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*BY* B. G. FORBES

## Summary

A dolomite-magnesite sequence, the Montacute Dolomite formation, occurs at scattered points northward from Adelaide at a constant stratigraphic level within the Adelaide System. The formation is richest in magnesite and contains very little arkose at Copley, while near Beetaloo it is rich in arkose, is thickest and contains much less magnesite. Individual units show little facies change over a few miles. The most common rock is dark grey dolomite, chiefly massive, but also laminated. Magnesite rock is generally a conglomerate, pale grey in colour. Dolomitic arkose forms a significant part of the succession in certain regions. Ripple marks, mud cracks, slump bedding and, in magnesite conglomerate, reverse graded bedding are common structures. Flow direction is indicated by sedimentary structures and by preferred orientation of grains.

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[Read 9 April 1959]

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The most common rock is dark grey dolomite, chiefly massive, but also laminated. Magnesite rock is generally a conglomerate, pale grey in colour. Dolomitic arkose forms a significant part of the succession in certain regions. Ripple marks, mud cracks, slump bedding and, in magnesite conglomerate, "reverse" graded bedding are common structures. Flow direction is indicated by sedimentary structures and by preferred orientation of grains.

## INTRODUCTION

The Proterozoic rocks of South Australia have for some time been known to contain deposits of magnesite, but the great extent and sedimentary nature of these deposits have been recognized only in recent years.

This paper covers the petrography and stratigraphy of the most notable formation containing these beds. A discussion of their origins is reserved for a later paper.

## METHODS

At most of the fourteen localities examined stratigraphic sections were measured from the top of the Aldgate Sandstones to the base of the Sturt Tillite of the Adelaide System. In addition, detailed examinations were carried out of that part of the section equivalent to the Montacute Dolomite formation, a collection made of oriented and other specimens, together with a record of directed sedimentary structures and the mapping of selected units.

Size distribution and preferred form orientation of grains in detrital rocks were determined both in thin section and on flat surfaces in the laboratory. Laboratory procedures included chemical analysis and qualitative tests, refractive index determinations, insoluble residue studies and routine examination of thin sections.

## DESCRIPTIVE STRATIGRAPHY

### GENERAL

Magnesite of the Adelaide System is confined largely (but not entirely) to the Montacute Dolomite or its equivalent, in the Torrensian Series, this formation in most areas being easily identified by its distinctive lithology and its stratigraphic position between the Aldgate Sandstones and the Sturt Tillite.

The composition and thickness of the formation at various localities are shown in Table 1. The positions of the localities appear in Fig. I, which also

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shows contours of thickness and sand-content. The table and figure are based on my own stratigraphic sections and those of Spry (1952), Wilson (1952) and Wymond (1950) at Hawker, Rhynie and Clare respectively. Fig. 1 is necessarily in part hypothetical.

TABLE I.

Properties of the Montacute Dolomite

| Locality | Thickness (ft.) | Percentage thickness of | | | |
|---|---|---|---|---|---|
| | | magnesite | Sand | Shale | Carbonate |
| 1. Adelaide (Torrens Gorge) | 550 | 2 | 14 | 3 | 83 |
| 2. Rhynie | 100? | 0? | 0? | little? | much |
| 3. Clare | 100? | 0? | 0? | little? | much |
| 4. Robertstown | 470 | 0 | 0 | little? | much |
| 5. Bundaleer | 450 | 1 | 27 | 7 | 66 |
| 6. Crystal Brook | 1400 | 1 | 40 | 7 | 53 |
| 7. Beetaloo | 2800 | 1 | 16 | 14 | 70 |
| 8. Pt. Germein | 2900 | 1 | 22 | 28 | 50 |
| 9. Mundallio Creek | 900 | 5 | 5 | 33 | 62 |
| 10. Depot Creek | 800 | 6 | 9 | 23 | 68 |
| 11. Johnburg | 600? | 8? | 12? | 43? | 45? |
| 12. Hawker | 1420 | 10 | 1 | 31 | 68 |
| 13. Copley | 2000 | 17 | 2 | 56 | 42 |
| 14. Arkaroola | 2300 | 7 | 6 | 6 | 88 |
| 15. Witchelina | 1600-2800 | 1 | 35 | 21 | 44 |

The greatest percentage thickness of magnesite is present in the northern Copley region. The formation itself is thickest in the Beetaloo region, where also there is a great thickness of sand of arkose composition. These associated facts suggest that near Beetaloo the area of accumulation was of the nature of a zeugogeosyncline (a basin of subsidence with complementary highlands nearby), to use Kay's (1951) terminology. It has not been found possible to correlate units between distant localities. However, diagrams showing percentage composition of various constituents per 50 or 100 feet have revealed general tendencies common to most sections. These are (1) a low proportion of dolomite near the middle of the succession and, in the same place, a high proportion of sand; (2) a high proportion of magnesite near the top of the succession.

## LOCAL VARIATION

Local facies changes in individual units could only be evaluated along the strike of outcrops. This study in particular is made difficult by the poor exposure of most carbonate rocks.

The Montacute Dolomite has not been recognized as such by the S.A. Department of Mines on either the Gawler or Echunga map sheets (respectively north and south of the Adelaide sheet). On the Adelaide sheet this formation shows rather rapid facies changes, expressed mainly in its disappearance to the north and east.

Thin magnesite beds at localities further north show little change where examined over one mile or more. The magnesite beds once worked by the B.H.P. Company at Mundallio Creek wedge out a little north of the Cardassis workings, but extend north for at least five miles from this point. Dolomitic

arkose beds at Beetaloo, Port Germein Gorge and Witchelina commonly thin out after being followed a mile or so along the strike.

It thus appears that magnesite beds are thin lenses of great extent (at least five miles diameter; perhaps 10-30 miles). Dolomite beds reach a greater thickness, and are probably more extensive. Dolomitic arkose beds are probably not as extensive as magnesite.

## PETROGRAPHY

### GENERAL

Rocks of the magnesitic succession are varied both in composition and fabric. The chief mineral component is dolomite, which forms a dark blue-grey dolomite rock or may be mixed with detrital quartz and feldspar, magnesite or argillaceous material. No calcite, even as a vein mineral, has been found in the magnesitic succession.

Magnesite and dolomite were distinguished by determining refractive index or a rapid turbidimetric determination of calcium, where special tests were necessary.

Contrasting properties of magnesite and dolomite rock are tabulated below:

| *Magnesite rock* | *Dolomite rock* |
|---|---|
| 1. Colour generally pale grey to white. | 1. Colour generally dark blue-grey. |
| 2. Occurs chiefly as a conglomerate, rarely as a breccia or massive. | 2. Occurs chiefly in the massive or laminated form. When fragmental it is a breccia, rarely a conglomerate. |
| 3. Individual beds are thin. | 3. Average thickness of beds greater than for magnesite. |
| 4. Occurs chiefly as pebbles when in rocks of mixed composition. | 4. Occurs chiefly as matrix when in rocks of mixed composition. |

### MAGNESITE ROCK

Components of magnesite rock are magnesite, talc, dolomite, authigenic albite, carbon, and detrital quartz and feldspar. Most magnesite rocks contain between 5 and 10 per cent. acid insoluble material.

Authigenic albite has been encountered only in a few specimens of magnesite conglomerate or arenite. Crystals are in most cases significantly located just inside the borders of magnesite pebbles. The idiomorphic albite has probably been derived by solution within the matrix of the conglomerate and deposition within magnesite pebbles. Detrital quartz and albite both show peripheral solution.

Dolomite is intimately mixed with magnesite or appears as detrital fragments in the matrix. It forms idioblastic rhombs more commonly than magnesite, and is generally coarser-grained than magnesite crystals, which are about $0 \cdot 002$ mm. in diameter. The term "crystal" is used to avoid confusion with detrital magnesite, such as magnesite pebbles which are aggregates of crystals, as also is massive magnesite rock.

Magnesite weathers to a white or cream colour irrespective of the colour of a fresh surface. This is a useful guide in distinguishing the rare dark varieties of magnesite from the normal grey dolomite.

Magnesite conglomerate and arenite are composed of rounded magnesite pebbles in a matrix of chiefly magnesite and dolomite. Individual pebbles range in diameter up to about 12 cm.

The size distribution of pebble long diameters in section has been studied

on a number-frequency basis. Results for six fine-grained conglomerates from Copley have been recalculated by Greenman's (1951) method to give cumulative curves. The following data were thus derived (Table 2):

TABLE 2.

Size Distribution of Magnesite Pebbles.

| Specimen A77 | Median diameter mm. (Md) | Sorting coefficient (So) |
| --- | --- | --- |
| 140 | 2·3 | 1·20 |
| 161 | 0·94 | 1·33 |
| 175A | 0·65 | 1·46 |
| 185 | 2·3 | 1·33 |
| 193 | 0·57 | 1·29 |
| 277A | 1·7 | 1·53 |

The conglomerates are all well-sorted.

The average of maximum pebble sizes for some localities, together with the average thickness of a magnesite bed for that locality is shown in Table 3.

TABLE 3.

Properties of Magnesite Conglomerate Beds.

| Locality | Number in Sample | Average largest pebble, mm. | Average Bed thickness, feet |
| --- | --- | --- | --- |
| Adelaide | 14 | 23 | 0·4 |
| Port Germein Gorge | 4 | 5 | 1 |
| Mundallio Creek | 25 | 18 | 1·6 |
| Depot Creek | 25 | 26 | 1·7 |
| Copley | 28 | 30 | 2·1 |
| Arkaroola | 23 | 8 | 1·4 |
| Witchelina | (rough estimate) | 3 | |

It was possible to collect at Copley individual magnesite pebbles which had weathered out of the conglomerate matrix. Sphericity has been calculated and shape plotted according to Zingg's method by determining for each pebble its volume and its largest, intermediate and shortest intercepts (a, b and c respectively). For 50 pebbles there is a preponderance of discs with b/a about 0·8 and c/b about 0·4. Average sphericity is about 0·65.

Certain characteristics of the pebbles—such as pinched or contorted margins, central depressed areas and curvature — cannot be represented numerically. Magnesite pebbles show no internal structure. Most conglomerates show preferred orientation of magnesite pebbles. This feature has been studied in sections parallel to bedding and in the vertical section parallel to the direction of preferred orientation. A distinction may be made between groups of low and high matrix content in the preferred orientation data. Rocks of low matrix content possess a larger number of pebbles at a high angle to the bedding than those of high matrix content. This is perhaps due to mutual interference of pebbles during deposition.

Magnesite breccia at Montacute occurs chiefly as thin zones of fragments which are lath-shaped in section. At Copley the breccias are thicker (up to

9 feet) and composed of a poorly-sorted mixture of dolomite and magnesite fragments in a dolomitic matrix. This matrix sometimes forms only a small proportion of the rock and may be crowded with small magnesite fragments. Large magnesite fragments are chiefly disc-shaped, but are traversed by cracks and possess irregular boundaries. Many plates have been bent. Others, in the section offered by the rock face are completely wrapped around portions of the matrix. Fragments show preferred orientation.

Massive or laminated magnesite occurs in thin beds, often at the base of magnesite conglomerate and has much the same composition as magnesite pebbles.

## DOLOMITE ROCK

Dolomites of the magnesitic succession are not chemically distinguishable from dolomite rock of other formations. Most of the analyzed dolomites are the common massive or laminated variety. They contain about the same proportion of insoluble material as non-fragmental magnesite, but less than that of the average magnesite rock.

Individual dolomite crystals are about 0·004 mm. diameter. Irregular dark chert nodules or lenses occur within some dolomite beds.

Massive or laminated dolomite varies between medium and dark grey. This is based on comparison with the chart of the Rock Colour Chart Committee (1951). The colour depends largely on carbon content and shows no systematic variation. Weathered surfaces of dolomite are pale bluish grey.

Dolomite breccia is very common in the Crystal Brook-Beetaloo region. The composition of angular dolomite fragments is the same as that of massive dolomite. Dolomite fragments are chiefly lath-shaped in section, and up to about 5 cm. long. Many laths are curved and arranged with their long axis parallel to the bedding. The rock contains about 70 per cent. volume of arenaceous matrix. Bedding planes are undisturbed.

## DOLOMITE-QUARTZ ROCKS

This group forms an important part of the magnesitic succession at Torrens Gorge, between Crystal Brook and Depot Creek, and at Witchelina. The term dolomitic arkose is applied to quartz-feldspar-dolomite rocks containing up to 50 per cent. dolomite. The majority of these rocks have 20 to 40 per cent. dolomite. Their fresh surface is very pale grey to dark grey and they weather to a pale brown.

Some arkoses show lamination due to alternation of fine and coarse layers. Imperfect graded bedding was seen in only one specimen.

Large quartz and feldspar grains are chiefly rounded to sub-rounded, while most grains (particularly quartz) are irregular in shape. Irregularity of shape is partly due to recrystallization and peripheral reaction with the carbonate matrix. Tiny cubes of pyrite are frequently present in the heavy fraction. Zircon occurs chiefly as well-rounded elongate grains whose size is proportional to the mean diameter for the rock. The predominant variety of tourmaline is brown and crystallized.

Magnesite is present in small amount either as matrix or detrital particles in some dolomite-quartz rocks. Dolomite, whether as matrix or discrete fragments, is most commonly very fine-grained. Some spherical dolomite particles possess at their centre an angular grain of quartz. A few rocks contain large patches of recrystallized dolomite as well as the normal fine-grained variety. The dolomite matrix may be completely recrystallized where there has been dynamic metamorphism. This is so at Torrens Gorge. Arenaceous dolomites are of wide

occurrence. At Torrens Gorge they are associated with magnesite breccia and at Crystal Brook with dolomite breccia.

Dolomitic arkose possesses a significant regional variation in properties. Table 4 below shows that, with the exception of Torrens Gorge, there are two petrographic "provinces".

TABLE 4.

Properties of acid-insoluble residues of Dolomitic Arkose

| Place | Feldspar% | Feldspar | Heavy Minerals | Mean size (mm) |
|---|---|---|---|---|
| Torrens Gorge | 11-38 | acid plagioclase | pink zircon | 0·09 — |
| Crystal Brook | 31-37 | microline | tourmaline | 0·76 |
| | | | (pink zircon) | 0·24 — |
| Port Germein Gorge | 37-47 | microline | pink zircon and | 0·43 |
| | | | tourmaline | 0·22 — |
| Mundallio Creek | 36-48 | microline | tourmaline | 0·41 |
| | | | (pink zircon) | 0·22 — |
| Copley | 35 | acid plagioclase | colourless zircon | 0·42 |
| Arkaroola | 21-30 | acid plagioclase | colourless zircon | 0·10 |
| | | | and tourmaline | 0·07 |
| Witchelina | 25(—) | acid plagioclase | colourless zircon | 0·07 |
| | | | and tourmaline | |

In the northern (Copley-Witchelina) province arkoses are finer-grained, contain acid plagioclase with little or no microcline, and colourless zircon as the chief heavy mineral. The mid-northern region (Crystal Brook-Mundallio Creek) is characterized by a larger mean size, microcline and pink zircon. The feldspar content is a little lower in the Copley-Farina group.

## CHERT

Two main kinds of chert may be recognized. One represents the silicification of separate fragmental carbonate beds while the other occurs as lenses and nodules within dolomite rock.

At Copley some thin chert beds extend for several miles. Other beds of similar fabric and composition occur as lenses within magnesite conglomerates. The cherts are dark-coloured, show a relict conglomerate or arenite fabric and are composed largely of fine-grained quartz and medium-grained dolomite, together with an extremely fine-grained material, possibly carbon.

Nodular chert within dolomite rock occurs as black or greyish lenses parallel to bedding. Short extensions of the nodules cut across the bedding. Sometimes lamination in the dolomite is diverted around the nodules.

Of four nodules examined in the laboratory, one showed lamination parallel to that of the enclosing dolomite, while the other three showed outlines of small elongate and rounded fragments.

It would seem that most chert was formed by the preferential silicification of fragmental carbonates either as distinct and separate beds of fragmental carbonates or as lenses of fragmental carbonates intercalated in massive rocks.

## ARGILLITE

Rocks of this group have been given little attention in the laboratory. Slates or siltstones do not form a significant part of the succession except at Witchelina. Colour is commonly dark grey or shades of blue- and green-grey. A reddish variant was noted at Copley.

## STRUCTURES

Ripple marks are common at Witchelina and are observed at the five northernmost localities. They are chiefly regular, with parallel ridges of low relief. They are found mainly on dolomitic arkoses and arenaceous rocks, but
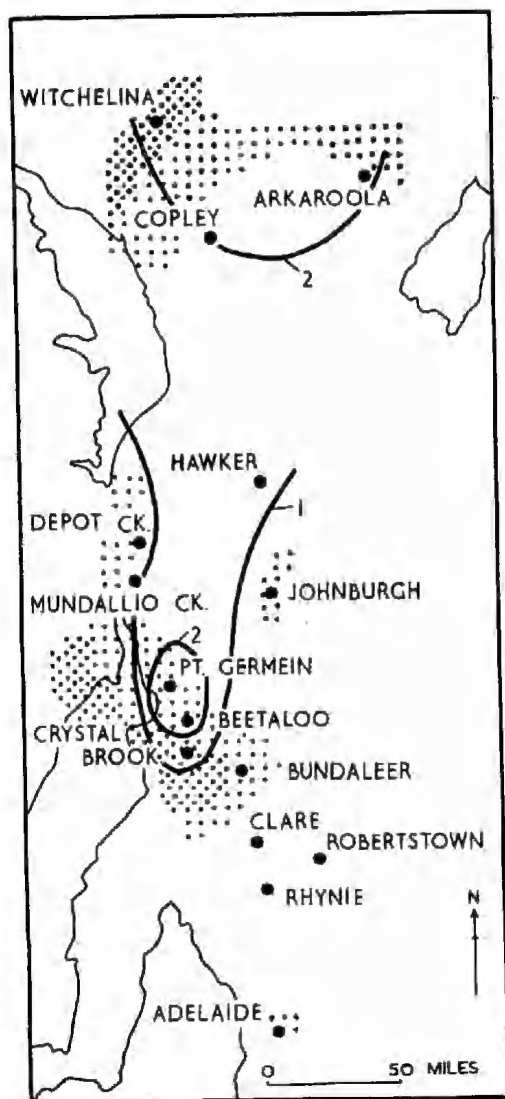


Fig. 1
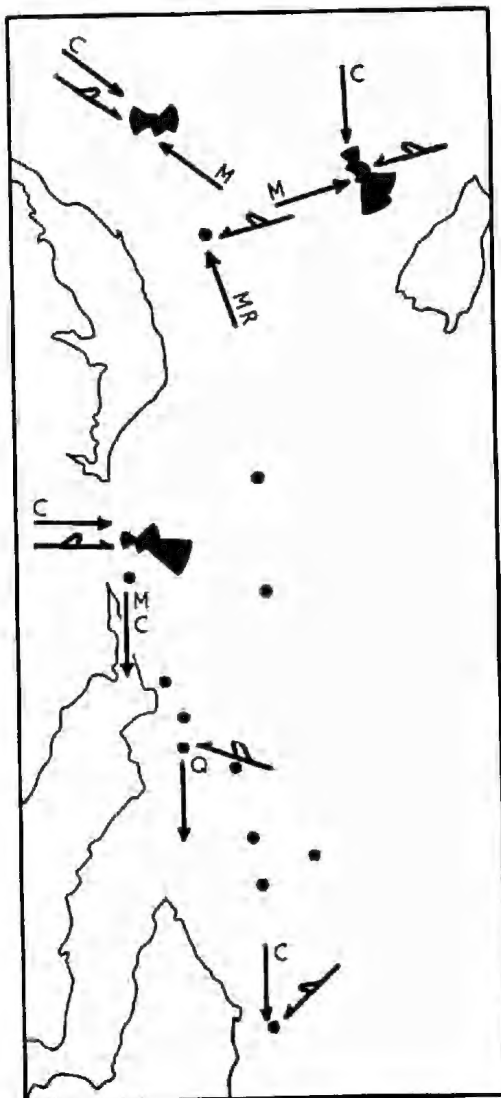
Fig. 2

Fig. 1.—Hypothetical lithofacies and isopach map of the Montacute Dolomite. Proportion of sand is shown by stippling: light stippling, 10-30 per cent.; dense stippling, greater than 30 per cent. Heavy lines are contours of thickness: figures indicate thousands of feet.

Fig. 2.—Flow directions as shown by sedimentary structures in the Montacute Dolomite. For explanation see text.

are also found in dolomite rock. About one-third of the ripple marks observed are slightly asymmetrical. Compound and arcuate ripples are much less common.

Mud cracks were noted in largest number at Copley and Arkaroola. They are present also at Depot Creek, Mundallio Creek and Witchelina. The structure is found in dolomite rock (paler-coloured varieties), dolomitic arkose and mixed rocks. Cracks range in size up to about half an inch across, and generally contain detritus (including small magnesite fragments) contrastingly coarser than the cracked layer. Polygons are up to ten inches in diameter, and are sometimes superimposed on ripple marks. The presence of coarse detritus within cracks indicates formation before burial of the cracked layer.

Slump structures are found in fine-grained sediments such as magnesite (massive) and dolomite rock. The vertical thickness disturbed is generally only a few inches. Brecciation due to slumping was seen only once. Both the slumping and brecciation were on a minute scale. Crests of slump folds are occasionally truncated by layers above.

Wavy bedding is a feature of laminated dolomite and some dolomitic arkoses. Irregularities in most places are only slight. In the sequence of arenaceous dolomites near Crystal Brook the amplitude of the crumpling is about 15 mm. Some of the folds are slightly overturned. At Torrens Gorge the structure is very common in banded dolomites. In some contorted bands the crests were several inches high, broke under pressure and allowed material to pass upward from the lower bed. Differential pressures during compaction of soft sediment would therefore appear to be an important factor here in the production of wavy bedding.

"Reverse" graded bedding is a persistent feature of magnesite conglomerate beds. Not all magnesite conglomerate beds show vertical grading, but when grading is present it is normally from finer-grained at the base to coarser-grained at the top. Beds showing reverse grading are from about 2 to 4 feet thick.

Both normal grading and current bedding are rare. Clay-pellet impressions are common in the siltstones and fine-grained arkoses of Witchelina.

## SUMMARY OF DIRECTIONAL STRUCTURES

Results obtained by various authors (e.g. Brett. 1955; McKee, 1954) show the palaeogeographic value of measuring numerous directional structures of sedimentary rocks. In the present study it is unfortunate that in most localities information of this kind is meagre. However, what is available is fairly concordant for each locality, and therefore significant. In Fig. 2 is a geographic summary of flow directions interpreted mainly from asymmetric ripple marks. Sufficient data were obtainable at Witchelina, Arkaroola and Depot Creek for representation by an orientation diagram. In other localities directions are indicated by arrows with a letter showing whether the inference is based on symmetric or asymmetric ripple marks (S or R), measurement in magnesite or quartzite of preferred orientation of grains (M or Q), or current bedding (C). The downwards tilt of the depositional surface causing slumping is indicated by a bent line.

## ACKNOWLEDGMENTS

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# CLASSIFICATORY SYSTEMS OF KINSHIP

*BY* H. K. FRY

**Summary**

# CLASSIFICATORY SYSTEMS OF KINSHIP

## By H. K. Fry

### [Read 9 April 1959]

Nearly a century ago Morgan published (1871) his monumental work on Systems of Consanguinity and Affinity. He had discovered that in many parts of the world every person in a society was included in one of several great classes of kinship terms. He deduced that systems of kinship could be explained "on the assumption of the antecedent existence of a series of customs and institutions, one reformatory of the other, commencing with promiscuous intercourse, and ending with the family as now constituted".

This hypothesis has not been sustained. It is now generally conceded that the family has always been the fundamental unit in human societies, and that kinship systems are correlated most significantly with existing social structures. However, Morgan's separation of kinship systems into the two divisions of the descriptive and the classificatory still holds good, and his tables of kinship terms of the classificatory systems include examples of most of the types recognised today.

There has been much controversy concerning the significance of these various types of classificatory kinship systems. McLennan (1876), who introduced the term exogamy, claimed that kinship terms were only terms of address. Kohler (1897) postulated that systems of the Omaha type were derived from a custom of marriages with the daughters of a wife's brother, and that systems of the Crow type were based on a custom of marriage with the wife of the mother's brother. Further observations have shown that Omaha-type systems are associated consistently with patrilineal societies, and Crow-type systems usually associated with matrilineal societies. Kroeber (1909) insisted that kinship terminology was not determined by, nor indicative of, a particular social organisation, but that linguistic and psychological factors were of primary, or at least equal, importance. Rivers (1914) strongly supported Kohler's hypothesis, and considered that social organisation was all-important in the determination of a system of kinship terminology. Radcliffe Brown developed the method of tracing the genealogical sequences of kinships, which later (1941) he termed the method of sociological analysis. He emphasised the importance of the structure of societies, and considered that the classificatory terminologies could be interpreted by reference to the principles of the unity of the sibling group and the unity of the lineage group.

For many years I have been using what may be termed a synoptic method in studying kinship systems. The basis of this method, which has been presented in previous papers (1931, 1934, 1950, 1957), is a set of symbols expressing in a marriage diagram the dominant custom of marriages between the social units of a society, and in a genealogical pattern the framework of the social structure emerging from such a system of marriages.

These symbols are based on the letters A a and B b representing male and female members respectively of family social units which intermarry. These are usually representatives of exogamous moieties A and B. Additional letters can be used when the more numerous primary divisions of phratries are in question. Numerals as prefixes are added to these letters to indicate member-

ship of successive generations. Numerals as suffixes are added to the letters to identify members of lines of descent differentiated by the kinship system. Marriages between members of these social units in each generation are indicated by the linkage = in the diagrams of marriage. The genealogical patterns are built up by arranging the symbols for all the representatives of one generation in a horizontal line, and plotting the symbols for sons below those of their respective fathers, and those of daughters below their respective mothers, in accordance with the appropriate diagram of marriages. Moiety or phratry identification of these children will be that of the father in a patrilineal society, that of the mother in a matrineal society.

The marriage diagrams and genealogical patterns can be simplified usually by relegating the prefixed numerals to the commencement of the series of symbols appropriate to each particular generation. Should this be done, any reference to any individual unit should include this numeral prefix; e.g., an individual unit of a series 1. A1 a1 B1 b1 should be referred to as 1A1, 1a1, 1B1, or 1b1.

Genealogical sequences can be followed readily in these patterns. By identifying *brother* and *sister* in one generation line, *father* and *mother* can be located in the line above, and are also *husband* and *wife* in that generation.

In a society with a classificatory kinship system, if all the genealogical interpretations of every kinship term be plotted on an appropriate genealogical pattern from the basis of a *brother* and a *sister* in one generation line as *Egos*, each of these terms will be found to be associated significantly with one recurring unit in the pattern.

This is a demonstration of the correlation of social structure and kinship terminology. It is more reasonable to postulate that a system of customary marriages between family groups determined social structure and therefore kinship terminology, than the alternative improbability that the members of a society elaborated a system of kinships to enable the obligations and privileges of certain social functions to be allocated to certain individuals and so determined their social structure.

Also, in primitive societies, it is most improbable that the acquisition of wives was limited by principles of eugenics; nor does it seem possible that abstract ideas of the unity of the sibling and the lineage groups were compelling forces in determining the sexual associations of men and women.

It is suggested that three general principles have applied with paramount importance to all classificatory kinship systems:

1. Although the fundamental social unit of the family is based on sexual association, sexual competition is the most disrupting force which social associations can experience. Therefore the elimination of sexual competition within the family unit must have been always a basic principle in shaping the development of human societies. It is the most obvious reason for the institution of exogamy.

2. The avoidance of sexual competition between father and son is of major importance in maintaining the integrity of the local family group.

3. The third principle is that in the human mind prohibitory ideas tend to radiate and involve associated concepts. Kinship terms, which have the significance of warning labels against sexual competition within the family, tend to be applied to families of associated or collateral lineages. The operation of this principle is fostered by the institution of totemism.

The first of these principles is axiomatic, evidence in support of the second and the third will be given in this paper.

Classificatory systems reached their most complete development in Australian aboriginal societies, which also exhibited many hallmarks of primitiveness owing to the isolation which they shared with their native fauna. Their systems, therefore, provide an exceptionally appropriate field for investigation. The members of all these societies were organised in totemic clans and family groups, and the clans were usually combined in two exogamous moieties. (Exact tribal boundaries are detailed in Tindale's (1940) map.)

Throughout Australia, with few exceptions, a man could marry only women of his own or his grandson's generation, and kinship terms alternated in and with alternate generations. Moieties were a feature of most Australian societies, and the normal function of the moiety is the demarcation of the clans, whose women the father or the mother's brother could marry, from those which the son or the sister's son could marry. The societies which divided moieties into named classes (sections) made the first division emphasise this distinction of alternate generations. In the Kamilaroi tribes of New South Wales marriage customs sometimes ignored the usual prohibition of marriage within the moiety and named class division of the same generation, but the class divisions defined sharply the prohibition of marriage between alternate generations as is shown in Figs. 1 and 2.

|  |  | *Dilbi* |  |  | *Kupathin* |
|---|---|---|---|---|---|
| 1. | **A** | **a** | **B** | **b** | |
|  | MURRI | matha | KUMBO | butha | |
| 2. | **B** | **a** | **A** | **b** | |
|  | IPPAI | kubbitha | KUBBI | ippatha | |
| 1. | **A** | **a** | **B** | **b** | |
|  | MURRI | matha | KUMBO | butha | |

Fig. 1

|  |  | *Dilbi* |  |  | *Kupathin* |
|---|---|---|---|---|---|
| 1. | **A** | **a** | **B** | **b** | |
|  | MURRI | matha | KUMBO | butha | |
| 2. | **A** | **a** | **B** | **b** | |
|  | KUBBI | kubbitha | IPPAI | ippatha | |
| 1. | **A** | **a** | **B** | **b** | |
|  | MURRI | matha | KUMBO | butha | |

Fig. 2

Over a large region in South and Western Australia alternate generations were distinguished as named groups. Many of these societies were even without moieties, but where the western peoples adopted conflicting systems of class nomenclature, these were so adjusted that a mother's class never became that of a wife (Elkin, 1940, p. 326).

All these facts seem to be significant in relation to the second principle mentioned above.

The prevalent custom throughout Australia, with the exception of some northern coastal districts, was that women were exchanged in marriage (a primitive feature), and that the marrying pairs were cousins "not too close up", in other words, that the women should not be of the men's father's or mother's clans. The marriage diagram expressing the simplest form of such a custom is that of Fig. 3.

1. $A1 = b1$   $A2 = b2$      2. $A1 = b2$   $A2 = b1$
    $a1 - B1$   $a2 - B2$        $a1 - B2$   $a2 - B1$

Fig. 3

The genealogical pattern corresponding to this marriage diagram in a patri-
lineal society is illustrated in Fig. 4, which is also the genealogical pattern typical
of a system of marriages between second cousins.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1. | A1 | A1 | B1 | b1 | A2 | a2 | B2 | b2 |
| 2. | A1 | b1 | B1 | a1 | A2 | b2 | B2 | a2 |
| 1. | A1 | a2 | B1 | b2 | A2 | a1 | B2 | b1 |
| 2. | A1 | b2 | B1 | a2 | A2 | b1 | B2 | a1 |
| 1. | A1 | a1 | B1 | b1 | A2 | a2 | B2 | b2 |

Fig. 4

This pattern is asymmetrical in regard to male and female lineages. Matri-
lineal and patrilineal forms of this pattern appear to represent the basic social
structure of the majority of aboriginal societies; that is, they are systems of the
Iroquois type, with sister exchange, and with the wife's clan distinguished from
that of first cousins. This is known in Australia as the Aranda type.

Aboriginal kinship systems can be grouped under two headings, those asso-
ciated with the inland tribes, and those associated with the marginal coastal
tribes (cf. Davidson, 1926).

The inland systems were matrilineal in the eastern half of the continent,
patrilineal in the western half. They were characterised by division into moieties
and usually also into named classes (sections).

The marginal coastal tribes often had no moiety divisions. They were
usually patrilineal, but matrilineal regions existed in recent times in the Swan
River district of Western Australia and in the north-western corner of Arnhem
Land. A former larger extension of these matrilineal areas is suggested by the
facts that kinship terms such as *kami, kaka, ngandri, nupa,* and *umali,* or their
analogues, are common to the matrilineal tribes of South Australia and the tribes
of southern Western Australia; also in northern Western Australia the class of
the child of an irregular marriage was determined by that of the mother.

The normal genealogical pattern of Fig. 4 being asymmetrical in regard to
male and female lines of descent, the pattern of kinship terms takes a some-
what different form in matrilineal and patrilineal societies. It is reasonable to
expect some simpler forms of kinship terminology as a compromise when tribal
units intermarry across the borders of these zones (Fry, 1934).

In the inland patrilineal regions of the Northern Territory and Western
Australia where inhospitable conditions could support only a sparse popula-
tion, which made every individual important, the kinship terminologies conform
most accurately to the Aranda pattern. Further, kinships in those areas were
stabilised and pin-pointed by the development of systems of eight named sub-
classes which conform completely with the pattern of Fig. 4. Marriage rules,
therefore, in these societies can be described in positive terms related to all
of the four male lineages of the Aranda genealogical pattern, e.g., mother's-
mother's-brother's-daughter's-daughter marriage, and so on. The usual condi-
tion, as Firth (1930) has pointed out, is "the kinship principle enters not as a
determinant but merely as a barrier against the union of close relatives".

The marginal coastal tribes were often of a stockier build than the inland
peoples, which might be a racial feature or related to a better food supply. They
usually did not practice circumcision. The clan organisation at times was
emphasised by the application of one kinship term to all the members of the clan
irrespective of generation. This again could be a racial feature, or dependent
upon a denser population due to a better food supply. It exemplifies Radcliffe
Brown's principle of the unity of the lineage group, but as a result rather than

as a cause of the social structure. Another possible feature of these systems was the maximal extension of marriage prohibition to any known relative by blood, exemplifying the third principle suggested earlier in this paper. Under these circumstances the significance of the distinction between the children of brother and sister diminished and was reflected in the kinship terminology. The kinship terminology of most of these marginal tribes was basically of the Aranda type with the exception of some northern tribes who did not practice sister exchange in marriage. But this tendency to fail to distinguish between the children of brother and sister meant that cross-cousins could be equated with siblings. Consequently, the kinship system approximated to the Hawaiian type. Elkin (1939, p. 215) drew attention to this feature in describing the kinship system of the tribes between the Bight and the Musgrave and Petermann Ranges, and suggested that these systems be known as the Aluridja type. Other examples of systems of the Aluridja type are the Bardi (Elkin, 1932a), the Daly River Tribes (Stanner, 1933, 1936), the Kattang (Elkin, 1932b), and the Kurnai (Howitt, 1904). The Yaralde (Radcliffe Brown, 1918) emphasised the clan organisation in their terminology, but did not adopt the Aluridja-type characteristics.

Radcliffe Brown described the Kariera kinship system (1913), as the type of a system based on a dominant custom of marriages of first cousins, and (1930, p. 452) as the norm of an earlier form of society in the evolutionary sense than the systems of second-cousin marriages typified by the Aranda. If, however, his male- and female-speaking kinship terms be integrated in one table (Fry, 1950), the Kariera kinship system conforms basically to the Aranda type but with Aluridja-type characteristics. The Kariera class system is frankly of Aranda type.

At the time of white colonisation the western and northern marginal tribes were apparently in the process of adapting named totemic groupings (phratries) to the named class (section) kinship divisions which were diffusing from Central Australia. The Swan River tribes (Grey, 1941; Salvado, 1886), Ingarda (Radcliffe Brown, 1930, p. 213), Bardi (Elkin, 1932a), Iwaidja (Wilson, 1835; Spencer, 1914), and the Melville Islanders (Spencer, 1914; Hart, 1930) may be cited as examples of tribes with a phratry organisation uninfluenced by the innovation of classes, and the Mardudhunera, Kariera (Radcliffe Brown, 1913), Karadjeri, Nyul-Nyul, and Lunga (Elkin, 1932a) as examples of compromise systems.

Unfortunately, the coastal tribes bore the brunt of the earliest conflict with colonisation with consequent detribalisation in most cases before adequate records of their social systems were attempted.

As mentioned previously, some of the marginal tribes on the northern coasts of Australia practised unilateral marriages and sister-exchange, if occurring, was rather complicated. Miss McConnel (1934, 1940, 1950) recorded the Wik-munkan system of this type which is based on marriage with the mother's younger brother's daughter, and marriage forbidden with the father's sister's daughter. Miss McConnel recognised six lineages in the social structure of this tribe, distinguished by their relative seniorities. The kinship terminology, however, was relatively simple. The Yir-Yoront was an analogous system (Sharp, 1934).

Warner (1930) described the Murngin system based on marriages unilaterally with the mother's brother's daughter. This kinship terminology is very complicated. I published (1950) a marriage diagram expressing a cycle of marriages between eight clans, the genealogical pattern of which conformed accurately with Warner's complex Murngin kinship terminology.

This marriage diagram is illustrated in Fig. 5, and the corresponding genealogical pattern in Fig. 6.
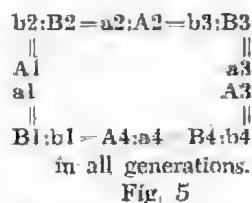
$$b2:B2=a2:A2=b3:B3$$
$$\|\qquad\qquad\qquad\qquad\|$$
$$A1\qquad\qquad\qquad a3$$
$$a1\qquad\qquad\qquad A3$$
$$\|\qquad\qquad\qquad\qquad\|$$
$$B1:b1=A4:a4\quad B4:b4$$

in all generations.

Fig. 5

| 1. | A1 | a1 | B1 | b1 | A2 | a2 | B2 | b2 | A3 | a3 | B3 | b3 | A4 | a4 | B4 | b4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2. | A1 | b1 | B1 | a4 | A2 | b2 | B2 | a1 | A3 | b3 | B3 | a2 | A4 | b4 | B4 | a3 |
| 3. | A1 | a4 | B1 | b4 | A2 | a1 | B2 | b1 | A3 | a2 | B3 | b2 | A4 | a3 | B4 | b3 |
| 4. | A1 | b4 | B1 | a3 | A2 | b1 | B2 | a4 | A3 | b2 | B3 | a1 | A4 | b3 | B4 | a2 |
| 1. | A1 | a3 | B1 | b3 | A2 | a4 | B2 | b4 | A3 | a1 | B3 | b1 | A4 | a2 | B4 | b2 |
| 2. | A1 | b3 | B1 | a2 | A2 | b4 | B2 | a3 | A3 | b1 | B3 | a4 | A4 | b2 | B4 | a1 |
| 3. | A1 | a2 | B1 | b2 | A2 | a3 | B2 | b3 | A3 | a4 | B3 | b4 | A4 | a1 | B4 | b1 |
| 4. | A1 | b2 | B1 | a1 | A2 | b3 | B2 | a2 | A3 | b4 | B3 | a3 | A4 | b1 | B4 | a4 |
| 1. | A1 | a1 | B1 | b1 | A2 | a2 | B2 | b2 | A3 | a3 | B3 | b3 | A4 | a4 | B4 | b4 |

Fig. 6.—The prefixed numerals refer to the class system.

I did not recognise the significance of this pattern, but later (1957) realised that it could be explained by the Wikmunkan system, but that the seniority principle had been extended a stage beyond that of the Wikmunkan.

Subsequently I learned that Laurence and Murdock (1949) had preceded me in publishing a description of the Murngin system as the expression of a cycle of marriages between eight clans. Radcliffe Brown (1951) strongly opposed this interpretation, claiming that it demanded a system of marriages with a father's father's sister's daughter's daughter's husband's sister's husband's sister's husband's sister's husband's sister's husband's sister, which Warner failed to observe. This genealogical sequence can be followed readily in Diagram 6 and the woman in question will be found to be also a mother's brother's daughter who is the normal marriage partner observed by Warner. Radcliffe Brown's criticism is therefore evidence in support of the interpretation which he sought to refute.

If the male and female symbols of the marriage diagram of Fig. 5 be transposed as in Fig. 7, the corresponding genealogical pattern will take a slightly different form from that of Fig. 6, but will present identical characteristics.
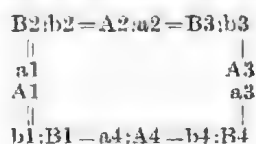
$$B2:b2=A2:a2=B3:b3$$
$$\|\qquad\qquad\qquad\qquad|$$
$$a1\qquad\qquad\qquad A3$$
$$A1\qquad\qquad\qquad a3$$
$$\|\qquad\qquad\qquad\qquad|$$
$$b1:B1=a4:A4=b4:B4$$

Fig. 7

These junior marriage systems provide another mechanism whereby sexual competition between father and son is avoided. Also, Miss McConnel recorded that when a man marries a woman of his grandson's generation, she must be of senior lineage in that generation.

If the marriages of Fig. 5 and 7 take place in alternate generations, father and son marry into alternate clans as in the Aranda system. The genealogical pattern corresponding to such a marriage diagram is of a type expressing a system of marriages with the father's sister's daughter but not with the mother's brother's daughter. Miss McConnel (1950) has described the Kandyu, neighbours of the Wikmunkan, as a society based on marriages with the father's younger sister's daughter.

It is interesting to note in these last two systems, where a man marries unilaterally a cross-cousin of junior status, that the forbidden cross-cousin is termed *cousin-mother*, and that her husband by the Wikmunkan is called *father*, and by the Kandyu *alma*, which is a term applied to a senior lineage. There is a hint here of the characteristics of the Omaha-Crow systems.

Sharp (1935) has noted the kinship system of the tribes on Mornington Island and the near-by coast of the Gulf of Carpentaria. Their marriages and kinship terminology normally follow the patrilineal Aranda pattern. However, three types of irregular marriages are permitted. The first is marriage with the mother's brother's daughter. The second is marriage with the daughter of the mother's brother's son and is associated with the use of the term *cousin-mother* for the mother's brother's daughter. As mother's brother's son's daughter is normally son's wife and termed *mother*, the term *mother* may be applied to three successive generations of women in the mother's brother's clan. The third form of irregular marriage is with a wife's father's sister or with a wife's brother's daughter. In the first and third types of irregular marriages the children are classified in the semi-moiety alternate to that of the father (e.g. A2 instead of A1). The first and second types entail members of the mother's brother's clan being termed *wife's father* in two successive generations if both types of marriage are contracted with that clan. The husband of *cousin-mother* is termed *father*. The kinship system of these tribes therefore includes several characteristics of an Omaha system in association with their irregular marriages.

The Kandyu marriage diagram exhibits one form of a permutation of unilateral marriages in alternate generations. Another type is that of Fig. 8.



Fig. 8.

The genealogical pattern of a patrilineal system corresponding to this marriage diagram is illustrated in Fig. 9.

Love (1941, 1950) has supplied data which provide sixty-five genealogical placements of kinship terms for the Worora tribe, a neighbour of the Ungarinyin and with the same organisation (Elkin, 1932a). The pattern of Fig. 9 conforms to all of these complex placements, which is reasonable evidence for its validity as a graphic representation of the Worora social structure.

The Worora, like other systems of the Omaha type, have a marriage custom whereby "a man may, and among the older men often has done so, marry another man's sister and his daughter" (Love, 1950). The Worora also apply one term, *waia*, to all the male members of the wife's clan irrespective of generation, which is a characteristic of the Omaha-Crow systems. The Worora also



Fig. 9

apply the same terms (*ibaia* and *ibanga*) to paternal cross-cousins and to nephew and niece, again an Omaha feature. The kinship terms of the mother's father's clan, however, alternate in alternate generations, and the maternal cross-cousins are equated with Ego's generation, although the wives of a mother's brother, his son, and his son's son are all termed *mother's mother* (*kadjanja*). The Ungarinyin apply the terms *kandingi*, mother's brother, and *ngadzi*, mother, to all members of the mother's father's clan irrespective of generation. Consequently, maternal cross-cousins are equated with mother's brother and mother, the paternal cross-cousins (*malengi*) again being equated with nephew and niece. The Ungarinyin kinship system therefore comes into full conformity with the type examples of an Omaha system.

There is one point in Elkin's description (1932a) of the Ungarinyin kinship system which can be challenged. He states that as the mother's mother (*kaiingi*) is the mother of *ngadzi*, mother's mother's brother's daughter cannot be a wife's mother. But actually *ngadzi* is of the clan *kandingi*, which is no reason why a woman of the clan *wolmingi* could not be a wife's mother. Elkin does not give the term for mother's mother's brother, but by analogy with the Worora system it should be *wolmingi*.

The avoidance of sexual competition between father and son is particularly interesting in these last-mentioned tribes. If Ego be 1A1 his wives are 1b2 and 2b2, whose sons respectively are 2A1 and 1A3. The wives of 2A1 are 2b4 and 1b4; the wives of 1A3 are 1b4 and 2b4.

The clans of many American Indian tribes were much more numerous than those of Australia. It is interesting to note that if the kinship terms of the Fox tribe (Tax, 1955), which is of the Omaha type, be plotted on the Worora genealogical pattern, all the lineages noted by Radcliffe Brown (1941) and many more will be found to be aligned with the clan lineages of Fig. 9.

No examples of the Crow type of system have been described in Australia. Spencer (1914) recorded marriages with the widow of a father and the widow of a mother's brother in the Kakadu tribe, but there is no evidence that these were customary practices or that they influenced the social structure. Probably these marriages were of no more significance than the information given to me by members of the detribalised Wailpi people that marriage with the father's sister was in order.

Kinship terminologies of the Crow type, such as those of the Banks Islanders (Codrington, 1891) or the Cherokee (Gilbert, 1955), do not conform to a matrilineal version of the Murngin pattern, but fall into neat lineages when charted on a matrilineal form of the Worora pattern. This suggests that although the kinship terminology may be influenced by marriage with the mother's brother's widow or wife, yet the social structure on which the terminology is founded is determined by marriages with women of clans which are more distantly related. This suggestion is supported by a statement of Codrington (1891, p. 244) concerning the Banks Islanders: "a woman when once the proper payment has been made for her, belongs to those that have paid, the family generally; hence a man, as in the story of Ganaviris, will set up his sister's son in life by handing over to him one of his wives, not because the young man has a right to his uncle's wives, but because the woman is already in the family".

The coastal tribes of Cape York Peninsula apparently exhibited another example of the operation of the principle of the radiation of prohibitory ideas. Miss McConnel (1950) has described the kinship systems of the Yaraidyana and Nggamiti tribes. These systems are apparently dependent upon the marriage of women of one lineage in three successive generations to men of different lineages (Fry, 1957).

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## CORRIGENDUM

In my paper Trans. Roy. Soc. S. Aust., 1957, 80, p. 4, line 3, instead of reference (Matthews and Everitt, 1900), substitute (Matthews, 1900), the latter reference in full being:
MATTHEWS, R. H., 1900. Marriage and Descent among the Australian Aborigines, Journ. Roy. Soc. N.S.W., 34, p. 120.

# SOME ACARINA FROM AUSTRALIA AND NEW GUINEA PARAPHAGIC UPON MILLIPEDES AND COCKROACHES AND ON BEETLES OF THE FAMILY PASSALIDAE

*BY* H. WOMERSLEY

## Summary

A new species of the genus **Heterocheylus** Lombardini, 1926, H. *lombardinii* sp. nov., is described from under the elytra of a Passalid beetle from Mt. Lamington, Queensland. This is the first record of the genus from Australia. The only other two described species are H. *fusiformis* Lomb., 1926, from Brazil and H. *lomani* Tragardh, 1950, from Africa. A key to the three species is given.

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Pt. 3.—The family Heterocheylidae

(Acarina-Trombidiformes)

### Family PSEUDOCHEYLIDAE Oudemans, 1909.

Oudemans, A. C., 1909, Tijds. v. Entom., 52 (1-2); pp. 19-61.

### Subfamily HETEROCHEYLINAE Trägårdh, 1950.

Trägårdh, I., 1950, Entom. Tidsk., 71 (2), p. 109.

### Genus HETEROCHEYLUS Lombardini, 1926.

Lombardini, G., 1926, Boll. Soc. Entom. Ital., 57 (1), pp. 160-1.

Type *Heterocheylus fusiformis* Lom., 1926.

In 1926 Lombardini erected this genus for *H. fusiformis* n. sp. found on a Passalid beetle from Brazil. In this paper he described and figured only the female, but later (Mem. Soc. Entom. Ital., 17 (1), p. 120, 1938) he briefly described and figured what he regarded as the nymphal male, also from a Brazilian Passalid.

In 1950 Trägårdh described and figured a second species *H. lomani* n. sp. from a single specimen from a Passalid from the Belgian Congo. Trägårdh placed *fusiformis* in the subfamily Heterocheyletinae, a mis-spelling for Heterocheylinae, now raised to family rank as the Heterocheylidae. In my present studies of the Acarina paraphagic on Passalid beetles, millipedes, etc., from Australia and New Guinea, a third species, *H. lombardinii* sp. nov., has been found on a Passalid (*Mastochilus* sp.) from Mt. Lamington, Queensland, December, 1948 (coll. H.W.). It is represented by three females and three nymphs (? males), now in the South Australian Museum collections.

### Heterocheylus lombardinii sp. nov.

Text Fig. 1, A-J

*Holotype female.*—Fig. A-H. Shape as figured and as in other species. Length overall 638μ, of idiosoma 522μ; width of idiosoma 278μ.

*Dorsal.*—*Gnathosoma* somewhat triangular, but slightly swollen apically just behind the mandibles, with a pair of minute setae immediately behind the chelicerae. *Propodosoma* anteriorly with two pairs of widely separated minute

[a] South Australian Museum.

setae, the posterior pair slightly nearer together than the anterior pair, posteriorly
and near to the posterior margin with a pair of closely adjacent conspicuous
clavate papilliform setae. *Hysterosoma* with four segments, the anterior (I)
somewhat hexagonal in shape, as long as wide, with a long 150$\mu$ lateral seta at
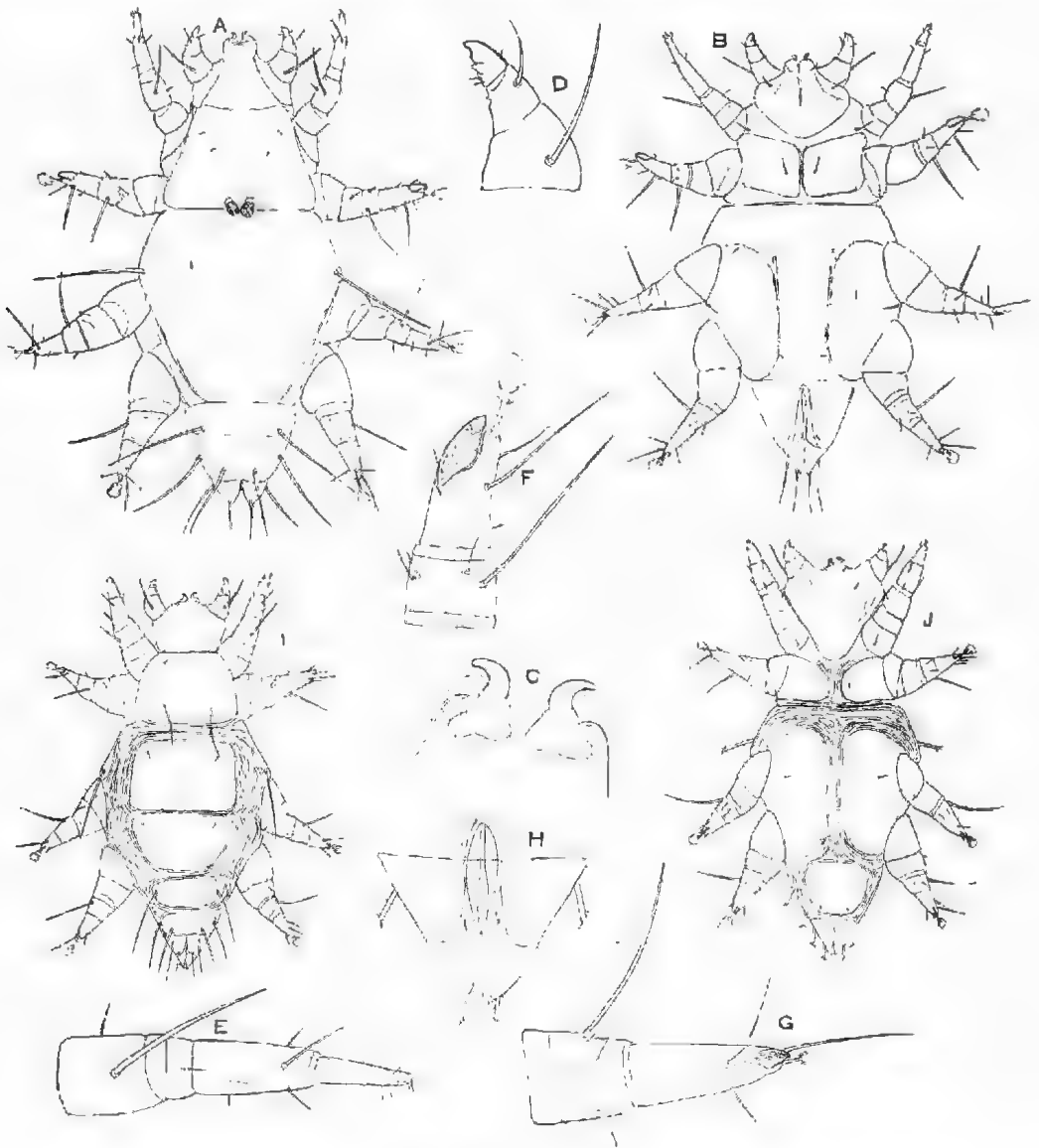


Fig. 1

*Heterocheylus lombardinii* sp. nov.  A-H.  Female; A, dorsal view; B, ventral view;
C, chelicerae; D, palp; E, leg I; F, tibia and tarsus leg II; G, tibia and tarsus
leg IV; H, genitalia.  I-J.  Nymph; I, dorsal view; J, ventral view.

the lateral angles; slightly in front of these and 132$\mu$ apart is a pair of minute
setae and midway between these and the posterior end of the segment is an-
other pair equally distant apart; segment II is rather collar-like, slightly more
than three times as wide as long, with a long setae 127$\mu$ in each posterior angle

and with a minute seta in front of each of these; segment III is about twice as long as II, with tapering sides and with two pairs of long setae, a mid-lateral one on each side 130μ long and a submedian subposterior pair 108μ long; segment IV is more triangular, bilobed with a longitudinal incision, a pair of lateral setae 127μ long and a pair of apical setae 66μ long situated one on the tip of each lobe.

The *mandibles* are small with the chelicerae outwardly curved and edentate. *Palpi* as figured, curved inwards and forceps like; femoral segment large, as broad as long with a long 62μ dorsal seta reaching to tip of palp; next segment as long as broad at its base with a finer dorsal seta 33μ long; the apical segment is a strong edentate claw with an inner basal accessory tooth and a pair of minute setae.

*Ventral.*—*Gnathosoma* with a pair of minute setae just behind the chelicerae and a longer one on each side at the base of the palpi. *Propodosoma* without epimera to leg I, but with a seta just behind the basal segment of the leg; epimera of leg II roughly rectangular, its inner margins confluent with each other in the medial line for about three-fourths of the length, the posterior margins are outwardly oblique a little in front of the propodosomal suture and not confluent therewith, there is a short seta on each side placed medially and near to the inner margins and not on shieldlets. *Hysterosoma* with the epimera of legs III and IV coalesced to form long shields separated medially by a strip of cuticle only slightly narrower than the shields, each shield is furnished with one seta near the anterior margin and one in the middle of epimera III, near the posterior end of the intervening ventral strip is another pair of small setae; posterior of legs IV, segments II, III and IV are confluent to form a single unit, which is tapering, and which bears the elongate genital orifice.

*Legs.*—All 7-segmented, short, fairly stout and tapering, I-IV of equal length 197μ; I is antennaeform, somewhat more slender than the others, and the tarsus without caruncle or claws; II-IV are much stouter, the tarsi ending in a strong small claw-like spine which is much larger on II than on III and IV, each tarsus also with a distinct caruncle, pad and a pair of fine minute claws.

*Nymph.*—Fig. I-J. As figured. Length entire 580μ, of idiosoma 464μ, width idiosoma 278μ.

*Dorsal.*—*Gnathosoma* as in adult. *Propodosoma* with shield completely covering dorsally, with two pairs of widely separated minute setae anteriorly as in adult, without the median posterior clavate setae of the adult but with a pair of long simple setae 108μ long, 89μ apart and 36μ from the posterior margin. *Hysterosoma* with four dorsal shields indicating the four segments as in the adult, but these shields except the fourth do not nearly cover the dorsal surface of the segment being surrounded laterally by longitudinal striations and separated from each other by transverse striations, the large shield of segment I, however, is divided medially into two parts, of which the anterior is rectangular, wider than long, and slightly longer than the posterior part, it is furnished with one pair of minute setae situated in the antero-lateral angles; the posterior part of this shield tapers posteriorly to a margin of about half the width of the anterior margin, it is wider than long and also furnished with a pair of minute setae in the antero-lateral angles, the pair of long lateral setae, 118μ long, are situated on small shields on the extreme margins of the body away from the shield itself; the shield on segment II is rather transversely oval, not extending right across the segment and furnished with one pair of sub-lateral long 104μ setae; the shield of segment III is similar but narrower, with one pair of lateral setae 75μ long and a pair of subposterior setae 75μ long;

the shield of segment IV covers the whole segment, is bilobed with a longitudinal fissure as in the adult and with two pairs of long setae 56µ and 33µ.

*Legs.*—As in the adult, all 174µ long; the claw-like spine on tarsi is small and of equal size on legs II-IV.

*Ventral.*—No epimera to leg I. Epimera of leg II roughly rectangular, not touching in the medial line and the posterior margin not confluent with the propodosomal suture, with one small seta in the medial angles. Epimera of legs III and IV confluent as in the adult forming two wide longitudinal shields separated by a narrower strip of the venter with distinct longitudinal striations, each shield has one small seta in the epimeral area of leg III, and there is another pair at the posterior end of the intervening striated strip. There is only a single roughly quadrate shield on segments II and III together which is furnished with one pair of small subposterior setae, this shield is encircled by striations. Segment IV is as figured, bilobed as in the adult.

*Remarks.*—This species is readily separated in the adult from the type species *H. fusiformis* Lomb. from Brazil in the pair of propodosomal clavate setae being set close together. In his species *H. lomani*, Trägårdh was unable to see these setae, but this species differs from both *fusiformis* and *lombardinii* in that the posterior margins of the epimera of legs II are confluent with the propodosomal suture.

Lombardini in his description of the nymph regards his specimen as a "nympham maris". This is somewhat hypothetical. In his figure he does not delineate any shields dorsally on the segments of the hysterosoma, but as he probably failed to notice their outlines by the striations it cannot be assumed that they were not present in his species. He does not figure the ventral surface.

Modifying Trägårdh's key to the species (*fusiformis* and *lomani*) the three species now known may be separated in the adult stage as follows:

### Key to the species of *Heterocheylus*.

1. Posterior margin of epimera II oblique and not confluent with propodosomal suture. .................................................................................................... 2

   Posterior margin of epimera II straight and contiguous with propodosomal suture. Ventral strip between epimera III and IV of equal width throughout—Belgian Congo.

   *H. lomani* Träg., 1950.

2. Clavate setae on propodosoma closely adjacent. Ventral strip between epimera III and IV slightly narrower than width of epimera and almost equally wide throughout — Australia.

   *H. lombardinii* sp. nov.

   Clavate setae on propodosoma widely separated by about four diameters. Ventral strip wider than epimera III and IV and much wider anteriorly than posteriorly — Brazil.

   *H. fusiformis* Lomb., 1926.

It is a pleasure to name the above new species after the creator of the genus, Prof. G. Lombardini of Florence, Italy.

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# NEW RECORDS OF SPECIES OF LEPTOLAELAPS (ACARINA, MESOSTIGMATA) FROM AUSTRALIA AND NEW ZEALAND

## *BY* H. WOMERSLEY

## Summary

The New Zealand species of *Leptoluelaps,* L. *reticulatus* Evans, 1957, is now recorded from moss from S. Australia, and *L. macquariensis* (Worn., 1937) is recorded from New Zealand. The hitherto unknown male of *macquariensis* is described.

# NEW RECORDS OF SPECIES OF LEPTOLAELAPS (ACARINA, MESOSTIGMATA) FROM AUSTRALIA AND NEW ZEALAND

By H. WOMERSLEY[*]

[Read 9 July 1959]

## SUMMARY

The New Zealand species of Leptolaelaps, L. reticulatus Evans, 1957, is now recorded from moss from S. Australia, and L. macquariensis (Wom., 1937) is recorded from New Zealand. The hitherto unknown male of macquariensis is described.

The genus Leptolaelaps Berlese, 1918, has recently been revised by Evans, 1957, and a key given for the six known species. These are elegans Berl. (the genotype) from the Transvaal, lambda Evans from Knysna, capensis Evans from Cape Province, and lawrencei Evans from Natal, reticulatus Evans from New Zealand and macquariensis (Womersley) from Macquarie Island.

All the known species are free living Mesostigmata occurring in moss and humus litter, except perhaps macquariensis which was recorded from "between tide marks, West Coast, Macquarie Island, 1913".

In the present paper two of the known species are recorded, namely, Leptolaelaps reticulatus Evans from South Australia, and L. macquariensis (Wom.) from New Zealand. Fresh drawings of these species are given, chiefly for accessibility by Australian students.

## Genus LEPTOLAELAPS Berlese, 1918

Leptolaelaps (subgen. of Hypoaspis Can.) Berlese, 1918, Redia 13, p. 122; emend. Evans, C. O., 1957, Ann. Natal Mus., 14 (1), p. 45. (Type Leptolaelaps elegans Berl., 1918.)

## Leptolaelaps reticulatus Evans

### Fig. 1, A-E

Leptolaelaps reticulatus Evans, 1957, Ann. Mag. Nat. Hist., 14 (1), p. 45.

Specimens of this New Zealand species have recently been obtained from moss from Upper Sturt, S. Australia (3 females), 24/8/58 (G. F. Gross), and moss from Myponga, S. Australia (3 females), 4/11/58 (H.W.).

A comparison of the accompanying figures of this Australian material with the description and figures of Evans of the New Zealand specimens confirms the specific identification. The only slight and unimportant differences are the lighter reticulation of the ventral shields and the prolongation of the sternum scarcely reaching the posterior margin of coxae III. Also the lateral sclerites of the genital shield, which in Evans' description and figure project posteriorly beyond the lateral margins of the shield as far as the posterior pair of adjacent lateral cuticular setae, only reach as far as the first pair of these setae. The male is still unknown.

The figures given here were made before a separate of Evans' paper was received when it was thought to be a new species of Leptolaelaps Berl.
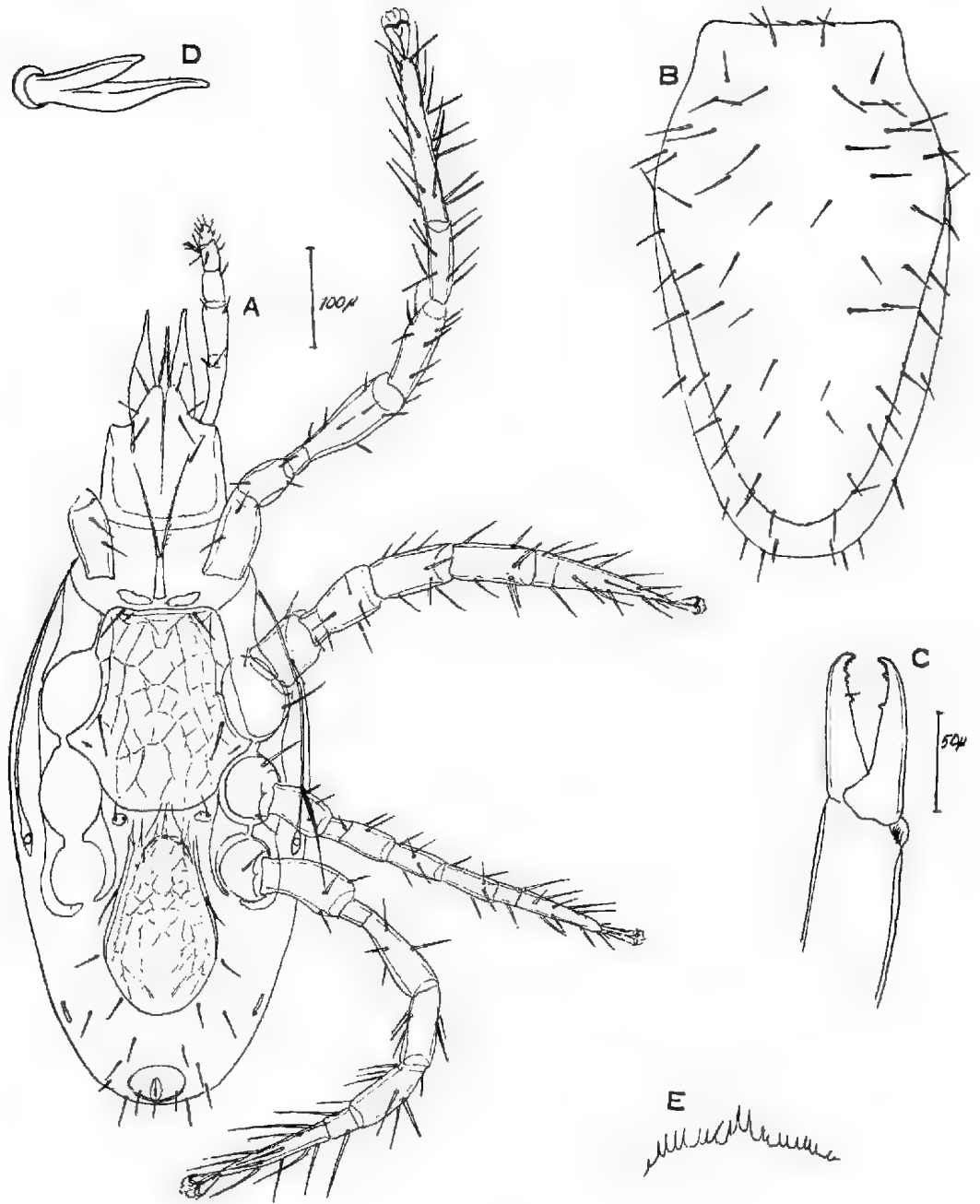
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[*] South Australian Museum.

Fig. 1.—*Leptolaelaps reticulatus* Evans, female: A, ventral view; B, dorsum; C, chelicerae; D, seta of palpal tarsus; E, tectum.

## Leptolaelaps macquariensis (Womersley, 1937)

Fig. 2, A-I

*Pachylaelaps macquariensis* Womersley, 1937, "Acarina" in "Sci. Repts. Australasian Antarctic Expedition, 1911-1914".

*Leptolaelaps macquariensis* Evans, 1957, Ann. Natal Mus., 14 (1), p 46.

This species was originally described and figured from a single female collected "from between tide marks, on the West Coast of Macquarie Is.", by the Australasian Antarctic Expedition, 1911-1914, led by the late Sir Douglas Mawson.

It was placed by Womersley in the genus *Pachylaelaps* Berlese, 1888, but Evans has shown that although closely allied to *Pachylaelaps* it is more properly to be put into *Leptolaelaps* Berlese, 1918.

In the South Australian Museum are a female and a male specimen received some years ago from an old correspondent, Mr. E. D. Pritchard, and collected from moss from Manurewa, New Zealand, 14th July, 1934.

These specimens have now been studied and found to be con-specific with the specimen from Macquarie Island.

The male sex has not hitherto been known and is herewith described and figured, while the opportunity is taken to re-describe the female sex from the additional specimens and to give fresh figures.

*Re-description of female* (from the New Zealand specimen).

Dorsal shield covering entire body and underlapping narrowly on to the venter right around, with about 35 pairs of setae to 50μ long, and some pores.

Ventrally.—The sternal shield is strongly reticulate with a more strongly marked median strip, anteriorly it is 178μ wide and the median length is 202μ, it is furnished with the usual 3 pairs of setae and 2 pairs of pores, it extends posteriorly to between coxae III and IV; the pre-endopodal shields are transversely elongate with concave anterior and convex posterior margins; the metasternal shields are distinct, small and roughly oval with seta 50μ long and a pore; the genito-ventral shield is flask-shaped with broadly rounded posterior, and only slightly longer than broad, 188μ by 164μ, it almost touches the anal shield and is furnished with only one pair of setae (genital) 50μ long, the lateral sclerites are distinct and reach to between the first and second of the adjacent lateral setae; the anal shield is pyriform and as wide as long, the anus is situated anteriorly and the paranal setae are in line with its posterior edge; the metapodal shields are small and roughly elliptical and lie in a line between the two setae laterad of the genito-ventral shield; on the cuticle between the genito-ventral shield and the anal is one pair of setae and on each side laterad of the anal is another pair of setae; the podal shields are well developed and extend slightly beyond coxae IV, and are coalesced with the exopodal shields; the endopodal shields of coxae II and III are coalesced but separated by a fine suture from those of coxae IV; the stigma lies between coxae III and IV and the peritreme extends to the level of coxae I, the peritremal shield is narrow and extends posteriad to middle of coxae IV and at the tip it is furnished with a small pore, anteriorly the shield is coalesced with the underlapping edge of the dorsal shield.

The base of the tritosternum is elongate and about 4 times as long as wide, it is furnished with the usual pair of ciliated laciniae. The gnathosoma is as figured with normal arrangement of setae; the palpi are 5-segmented and 216μ long with the specialised tarsal setae 2-tined; the cornicles are long and slender, 94μ long, and reach almost to the tip of palpal segment II, they are flanked by the equally long and elongate salivary stylets. The tectum is as figured with a short median mucro and about 9 denticles on each side. The
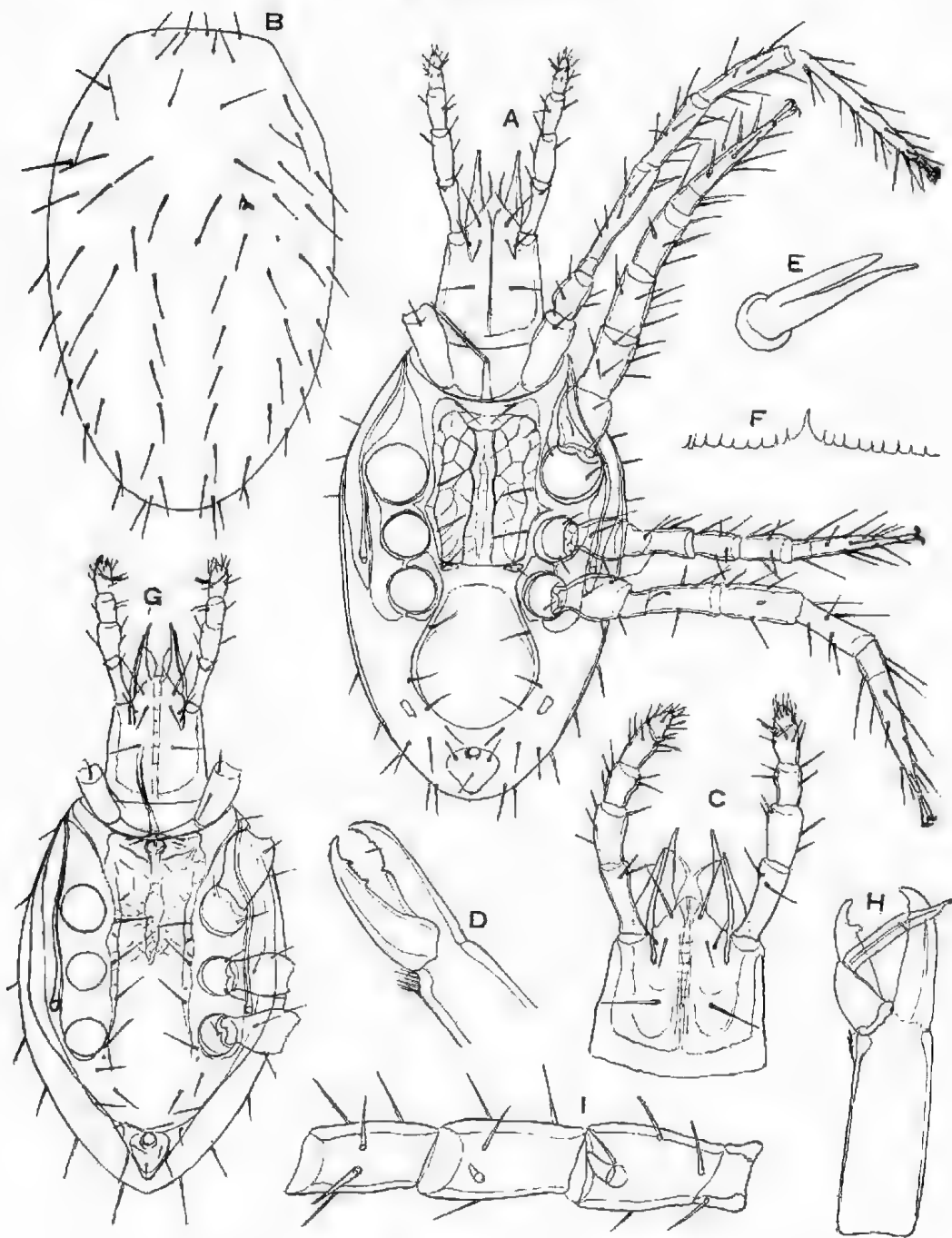
Fig. 2.—*Leptolaelaps macquariensis* (Wom.). A-F, female: A, ventral view; B, dorsum; C, gnathosoma; D, chelicerae; E, seta of palpal tarsus; F, tectum. G-I, male: G, venter; H, mandibles; I, femur, genu and tibia leg I

chelae are as figured, the movable digit with two moderately strong teeth between which is a number of minute teeth, the fixed digit has two moderate teeth and several smaller ones, with a short pilus dentalis.

The legs are generally slender, I and IV being longer than the idiosoma; I 730μ long, tarsus with slender geniculate caruncle and paired claws; II rather stouter 580μ long with normal caruncle; III 487μ long; IV 696μ long; III and IV more slender than II and the setae on tarsi to 70μ long.

*Dimensions of idiosoma*, length 603μ, width 370μ.

*Description of Male Allotype.*—General facies as in female. Dorsal shield covering body and underlapping venter more than in female, especially posterolaterally (see Fig. 2G).

Ventrally, the sternal, genital and ventral shields coalesced into a single shield which is broadly rounded posteriad of coxae IV and almost reaches the anal shield, anteriorly it is reticulate much as in the female, it is furnished with 9 pairs of setae and the usual pores, it is 376μ long; the anal shield is 56μ long by 56μ wide and shaped as in the female.

Gnathosoma as in female; palpi 211μ long; cornicles 85μ long. The chelicerae as figured, movable digit 66μ long with only one strong tooth and furnished with a fairly thick and long spermatophoral process.

Legs as in female, except that femur and genu of II with strong processes as in Fig. 2 I, I 696μ long, II 522μ, III 452μ, IV 626μ.

*Dimensions of idiosoma*, length 522μ, width 324μ.

*Locality.*—One female and one male from moss, Manurewa, New Zealand, 14/7/34 (coll. E. D. Pritchard).

*Type.*—The male allotype and the female specimen are in the collection of the South Australian Museum. The female has been dissected, the gnathosoma and mandibles on one slide and the rest of the mite on another.

## REFERENCES

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EVANS, G. O., 1957. Annals Natal Mus., 14 (1), pp. 45-57.

# NEW RECORDS OF SPECIES OF LEPTOLAELAPS (ACARINA, MESOSTIGMATA) FROM AUSTRALIA AND NEW ZEALAND

*BY* H. WOMERSLEY

## Summary

The New Zealand species of *Leptoluelaps,* L. *reticulatus* Evans, 1957, is now recorded from moss from S. Australia, and *L. macquariensis* (Worn., 1937) is recorded from New Zealand. The hitherto unknown male of *macquariensis* is described.

# A NEW GENUS AND SPECIES LAELAPTOSEIUS NOVAE-ZELANDIAE FROM NEW ZEALAND (ACARINA, ACEOSEJIDAE)

## By H. WOMERSLEY*

### [Read 9 July 1959]

### SUMMARY

A new genus *Laelaptoseius* and a new species *L. novaezelandiae* are described from New Zealand.

### Genus LAELAPTOSEIUS nov.

With entire dorsal shield with scabrous reticulations. Legs I and IV longer than body. Pre-endopodal shields present. Sternal shield with three pairs of setae and reaching to middle of coxae III. Metasternal shields present with seta and pore. Genital shield with truncate base. Peritreme on the inner margin of well chitinised, strongly reticulated, wide, lateral shields which extend posteriorly beyond coxae IV. Metapodal shields conspicuous and round. Tectum denticulate.

### Laelaptoseius novae-zelandiae sp. n.

#### Fig. A-II

*Types*—Two females collected from humus from Manurewa, New Zealand, 2/9/34 (coll. E. D. Pritchard).

*Location*—The holotype and one paratype are in the collection of the South Australian Museum.

*Description*—Female: A rather large, broadly oval, well sclerotised mite. Idiosoma 1088μ long, 760μ wide.

*Dorsum*—Dorsal shield entire and covering the whole body with scale-like reticulations and about 32 pairs of simple setae which are fairly thick basally and tapering to a fine point to 70μ long.

*Venter*—Pre-sternal shields present, transversely ovoid; tritosternum with elongate base and a pair of ciliated lacinia; sternal shield as figured with lightly concave anterior margin and somewhat less so posterior margin, anterior width 197μ, posteriorly across arms between coxae II and III 235μ, length in median line 188μ, furnished with rather strong reticulations especially medially, with three pairs of setae to 56μ long and two pairs of pores; metasternal shields conspicuous with seta 47μ long and a pore; genital shield about as long as wide, with truncate posterior margin, length 210μ, width across base 210μ, with one pair of setae 47μ long and 160μ apart, with strong reticulations; immediately behind the posterior margin is a line of four transverse lenticular small shieldlets; the anal shield is well separated from the genital shield, it is roughly triangular, about as wide as long with rounded anterior and on each side with a conspicuous outstanding pore on the margin; the cuticle carries about eight setae on each of which two pairs lie between the genital and anal shields; the metapodal shields are fairly conspicuous and round; the stigma lies between coxae III and IV and the peritreme runs forward to coxae I on the inner edge of a large podal shield which extends laterally to the body margin and posteriorly beyond coxae IV, laterally this shield is confluent with the body margin to the shoulders, and is remarkably reticulate, length of shield 487μ, width 200μ.

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* South Australian Museum.

*Gnathosoma* as figured with four pairs of hypostomal setae, cornicles small; palpi with 2-tined tarsal seta, and a pair of specialised setae (Fig. H) on inside of genu. *Chelicerae* as figured, movable digit with two teeth, fixed digit with two teeth. *Tectum* denticulate. *Legs*—Generally slender, tarsi with caruncle, a pair of claws and a pad; I and IV as long as or longer than idiosoma, I 1250$\mu$, II 849$\mu$, III 839$\mu$, IV 1110$\mu$.

*Male*—Unknown.

*Remarks*—In the form of the genital shield, and in the truncate posterior margin of that shield, this genus is provisionally in the absence of the male placed in the family Aceosejidae Baker and Warton, 1952, as given in the key to the families of the Mesostigmata-Parasitoidea by Evans, 1957.
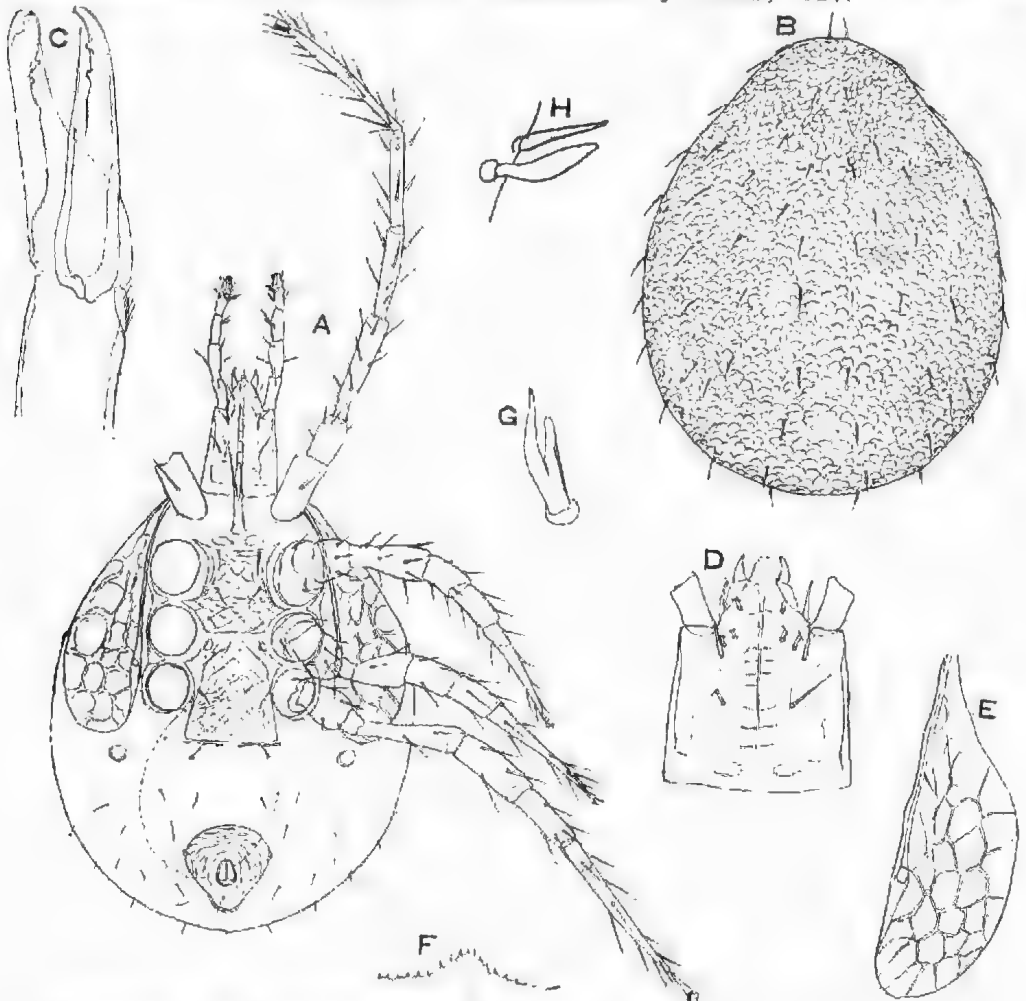


Fig. 1

*Laelaptoseius novae-zelandiae* g. et sp. nov. Female: A, ventral surface; B, dorsum; C, chelicerae; D, gnathosoma from below; E, peritremal shield; F, tectum; G, palpal tarsal seta; H, sensillae on genu of palp.

## REFERENCES

Baker, E. W., and Wharton, G. W., 1952. *An Introduction to Acarology*. New York.

Evans, G. O., 1957. An Introduction to the British Mesostigmata (Acarina) with keys to families and genera, J. Linn. Soc. London, 43 (291), pp. 203-259.

# A SECOND SPECIES OF PRISTOLAELAPS (ACARINA, LAELAPTIDAE) FROM AUSTRALIA

*BY H. WOMERSLEY*

## Summary

The genus *Pristolaelaps* was described by Womersley, 1956, with P. *tasmanicus* sp. n. as genotype. Further records of this species are here given for South Australia and a second species P. *obovata* sp. n. is described from Victoria.

# A SECOND SPECIES OF PRISTOLAELAPS (ACARINA, LAELAPTIDAE) FROM AUSTRALIA

## By H. WOMERSLEY[*]

[Read 9 July 1959]

## SUMMARY

The genus *Pristolaelaps* was described by Womersley, 1956, with *P. tasmanicus* sp. n. as genotype. Further records of this species are here given for South Australia and a second species *P. obovata* sp. n. is described from Victoria.

The genus *Pristolaelaps* with *P. tasmanicus* sp. n. as the type was described by the writer (1956) and the genus defined as follows:

"*Female.*—Elongate oval, with undivided dorsal shield entirely covering dorsum. Palpal tarsus with 2-tined seta. Pre-endopodal shields present. Sternal shield longer than wide with three pairs of setae. Metasternal shields only represented by seta. Genital, ventral and anal shields coalesced, the combined shield widened behind coxae IV. Exopodal shields fused and extending widely behind coxae IV. Peritremal shield separated from exopodal by a narrow line of cuticle, ending opposite coxae IV and with stigma between coxae III and IV. Legs slender, unarmed.

*Male*—Unknown.

*Genotype—Pristolaelaps tasmanicus* sp. nov."

With the discovery of the following second species of the genus, the above diagnosis requires amending in some minor details. The shape varies from elongate oval to broadly oval and the sternal shield may be about as long as wide as well as longer than wide.

## Genus PRISTOLAELAPS Womersley, 1956.

*Pristolaelaps* Womersley, 1956, "On some new Acarina-Mesostigmata from Australia, New Zealand and New Guinea," J. Linn. Soc. London, Zoology, 42 (228), p. 571. (Type: *Pristolaelaps tasmanicus* sp. nov.)

## Pristolaelaps obovata sp. nov.

### Fig. 1, A-E

*Types.*—Holotype female and one paratype female in the collection of the South Australian Museum.

*Locality.*—Koroit, Victoria, August 23rd, 1935 (coll. R. T. M. Pescott).

*Description of Female.*—A very strongly chitinised, dark brown species of broadly oval shape.

*Dorsum* with entire dorsal shield which underlaps narrowly on to the venter, surface smooth and apparently without setae except for a few minute ones on the underlapping strip.

*Venter.*—Generally as figured and as in the genus with the genital, ventral and anal shields coalesced and expanded behind coxae IV. Pre-endopodal shields present and transversely elongate; sternal shield about as long as broad with concave anterior margin and almost straight posterior margin, with 3 pairs of setae $47\mu$ long and in almost straight oblique lines, with 2 pairs of pores,

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[*] South Australian Museum.

length of shield in median line 99$\mu$, maximum width 197$\mu$; metasternal shields absent and only represented by the setae; genito-ventri-anal shield large and occupying most of the venter behind coxae IV, anterior margin lightly rounded and fibrillated, expanding behind coxae IV to 300$\mu$, then rounding to include the anus, with 5 pairs of setae besides the 3 anal setae, surface faintly reticulate; endopodal shields of coxae III and IV distinct; exopodal shields coalesced and produced behind coxae IV as a triangular podal shield; metapodal shields
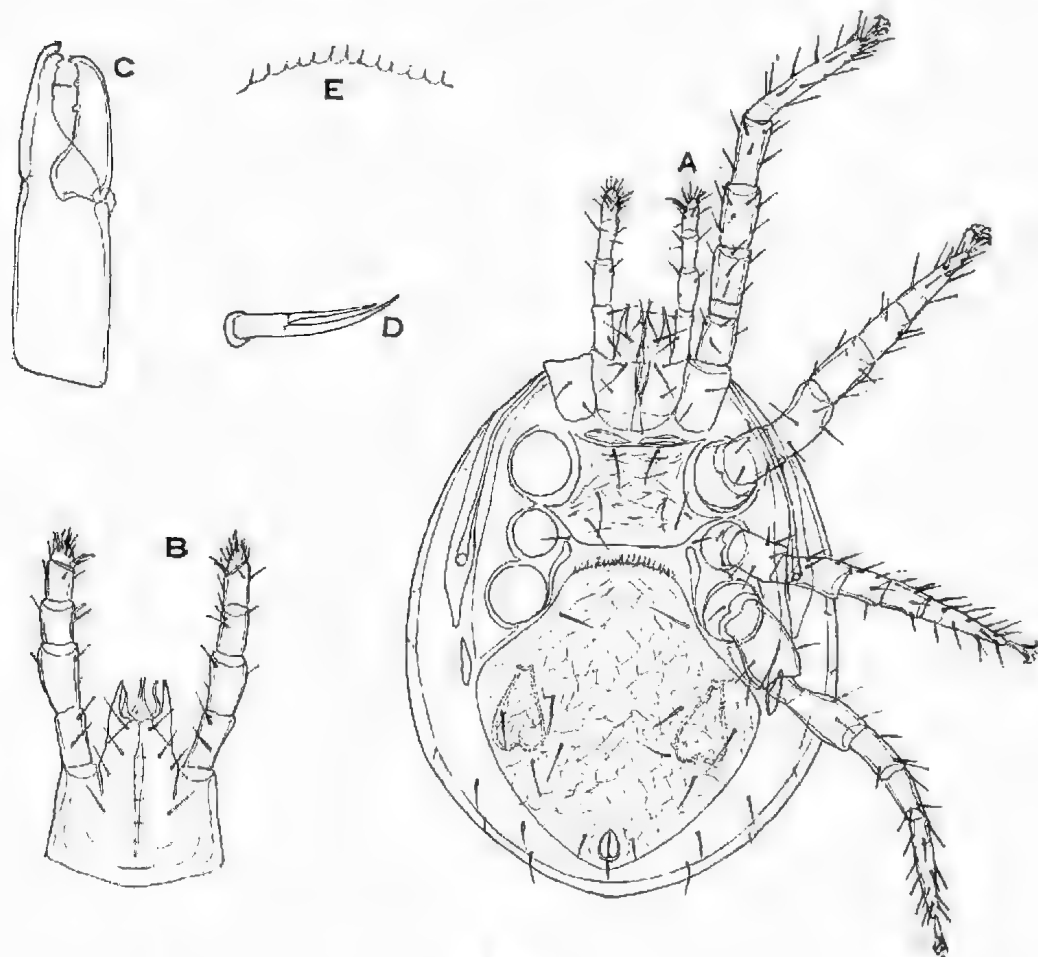


Fig. 1

*Pristolaelaps obovata* sp. nov.   Female: A, venter; B, gnathosoma from below; C, chelicerae; D, tined seta of palpal tarsus; E, tectum.

elongate oval.  Stigma between coxae III and IV and peritreme running forward to coxae I, on a distinct peritremal shield well separated from the exopodal shields, rather widened in the region of the stigma and extending posteriad to the margin of coxae IV.  On the cuticle laterad of the genito-ventri-anal shield with 3 long setae on each side.  A pair of well chitinised spermatheca are clearly to be seen (Fig. 1 A).

*Gnathosoma* as figured; palpi and cornicles normal.

*Chelicerae* as figured, movable digit with two small teeth, fixed digit with a prominent subapical tooth and four smaller ones, two on each side of the pilus dentilis. Tectum denticulate.

*Legs* all shorter than idiosoma, I 598$\mu$ long with normal ambulacral arrangement, II 383$\mu$, III 360$\mu$, IV 487$\mu$; all without special armature. Dimensions of idiosoma, length 580$\mu$, width 464$\mu$.

*Remarks.*—This species differs from the genotype in the much greater sclerotisation, its broader shape and in the length and shape of the sternal shield.

## Pristolaelaps tasmanicus Womersley, 1957

*Pristolaelaps tasmanicus* Womersley, 1957, J. Linn. Soc. London, Zoology, **42** (228), p. 571.

*New Records.*—Originally described from Burnley, Victoria, on strawberry plants imported from Tasmania, this species has now been found in moss from:

Upper Sturt, S. Australia, 19/9/58 (G. F. Gross).

Naracoorte, S. Australia, 8/1/59 (P. Aitken).

# THE CHARNOCKITIC GRANITES AND ASSOCIATED GRANITES OF CENTRAL AUSTRALIA

BY *ALLAN F. WILSON*

## Summary

Igneous rocks from a long E.-W. belt in Central Australia vary in type from orthopyroxene granites in the Musgrave Ranges through augite-hornblende granites to hornblende granites and sphene-biotite granites in the Ayers Ranges and Kulgera Hills. Ferrohypersthene granites form large meridionally-trending discordant masses in meridionally-trending synclinoria of hypersthene granulites in the Musgrave Ranges. Field study indicates a fluid (or magmatic) emplacement of the partly crystalline granite. In the Ayers Ranges similar pseudophacolithic granite masses are hornblende-bearing (and devoid of orthopyroxene). The basement metamorphic rocks there are of amphibolite facies. A regional deep-seated E.-W. downwarp (possibly associated with deepseated E.-W. transcurrent shearing) may have been sufficient to have caused a thorough reconstitution of the basement rocks (now represented by hypersthene-bearing, or hornblende-bearing granulites of many types), and the development of "pockets" of potential magma in favoured areas. It is further postulated that subsequent emplacement of the resulting rheomorphic masses would have been assisted by pre-existing weaknesses such as those due to the N.-S. attitude of many of the original rocks. This may explain the apparent anomaly of E.-W.-trending granites which are often found within rocks of N.-S. tectonic trend, and could throw light on some of the lineation problems in parts of Central Australia. A superimposed metamorphism (initially more thermal than dynamic) of already highly metamorphosed rocks could explain some of the "anomalous" mineralogic and textural features of certain charnockitic granulites. Thus, in the Musgrave Ranges charnockitic rocks of more than one origin have been found. The charnockitic granites, for which a part-fluid, part-metasomatic origin is postulated, differ structurally from the charnockitic granulites of the basement, for the granites have been magmatically emplaced. They also differ mineralogically, that the mafic minerals of these granites are consistently more ferriferous (and otherwise different) than the corresponding minerals of the basement rocks. This is well illustrated by the different trends of compositional tie-lines of co-existing pyroxenes in the two groups of rocks. The Ernabella Adamellite, the Ayers Ranges Adamellite, the Kulgera Adamellite are formally named and described. Eight new chemical analyses of granites (including three of orthopyroxenic granites), much mineralogic and petrographic data, are included in this paper.

# THE CHARNOCKITIC GRANITES AND ASSOCIATED GRANITES OF CENTRAL AUSTRALIA

by Allan F. Wilson[*]

[Read 9 July 1959]

## SUMMARY

Igneous rocks from a long E.-W. belt in Central Australia vary in type from orthopyroxene granites in the Musgrave Ranges through augite-hornblende granites to hornblende granites and sphene-biotite granites in the Ayers Ranges and Kulgera Hills. Ferrohypersthene granites form large meridionally-trending discordant masses in meridionally-trending synclinoria of hypersthene granulites in the Musgrave Ranges. Field study indicates a fluid (or magmatic) emplacement of the partly crystalline granite. In the Ayers Ranges similar pseudophacolithic granite masses are hornblende-bearing (and devoid of orthopyroxene). The basement metamorphic rocks there are of amphibolite facies.

A regional deep-seated E.-W. downwarp (possibly associated with deep-seated E.-W. transcurrent shearing) may have been sufficient to have caused a thorough reconstitution of the basement rocks (now represented by hypersthene-bearing, or hornblende-bearing granulites of many types), and the development of "pockets" of potential magma in favoured areas. It is further postulated that subsequent emplacement of the resulting rheomorphic masses would have been assisted by pre-existing weaknesses such as those due to the N.-S. attitude of many of the original rocks. This may explain the apparent anomaly of E.-W.-trending granites which are often found within rocks of N.-S. tectonic trend, and could throw light on some of the lineation problems in parts of Central Australia. A superimposed metamorphism (initially more thermal than dynamic) of already highly metamorphosed rocks could explain some of the "anomalous" mineralogic and textural features of certain charnockitic granulites.

Thus, in the Musgrave Ranges charnockitic rocks of more than one origin have been found. The charnockitic granites, for which a part-fluid, part-metasomatic origin is postulated, differ structurally from the charnockitic granulites of the basement, for the granites have been magmatically emplaced. They also differ mineralogically, in that the mafic minerals of these granites are consistently more ferriferous (and otherwise different) than the corresponding minerals of the basement rocks. This is well illustrated by the different trends of compositional tie-lines of co-existing pyroxenes in the two groups of rocks.

The Ernabella Adamellite, the Ayers Ranges Adamellite, the Kulgera Adamellite are formally named and described. Eight new chemical analyses of granites (including three of orthopyroxenic granites), much mineralogic and petrographic data, are included in this paper.

## INTRODUCTION

Large masses of granite occur throughout the arid mountainous country which extends E.-W. for 300 miles along the South Australian-Northern Territory border in Central Australia (Fig. 1). In hand-specimen some of these granites (especially the orthopyroxenic) cannot be distinguished from typical charnockites of India. Others are augite-, or hornblende-, or biotite-bearing granites, and some are very coarsely porphyritic.

The granites cut a gneissic complex of granulite facies throughout much of the Musgrave Ranges, and of high amphibolite facies in the Ayers Ranges and Kulgera Hills.

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Brief mention of some of the geomorphologic features of this area has been made in other papers (Wilson, 1947a, 1947b).

## THE FIELD WORK

The field work was done from Dec. 1943-Feb. 1944; Dec. 1945-Jan. 1946; Dec. 1948-Feb. 1949, and Jan.-Feb. 1952. The field work was hampered by bad seasons and summer heat, and by inadequate equipment and research funds. Air-photographs were available only for the Ayers Ranges for the fourth expedition (see foot note, p. 39). Some of the difficulties of mapping this terrain have been mentioned elsewhere (Wilson, 1947b, p. 196).

## PREVIOUS WORK

Although most of the early explorers remarked on the large expanses of "granite" occurring in these regions, few geological details were given (e.g., Giles, 1874; Gosse, 1874; and Forrest, 1875). Brown (1890) and Streich (1893) make brief mention of the coarse porphyritic granite of the Everard Ranges, but Basedow (1905) seems to have been the first geologist to attempt a structural synthesis of the granitic rocks of the Musgrave Block. His petrographic notes, however, are scant. Robinson (1949) has since published good descriptions of some of Basedow's rocks.

Lockhart Jack (1915) made valuable structural observations of the granitic rocks, especially of the Everard Ranges, and suggested that the granites of the Musgrave Ranges were probably co-eval with the Everard Ranges granite (p. 16). In 1947, the present author published the first of several papers dealing with petrological and structural features of the main granitic rocks of the Musgrave Ranges and the Kulgera Hills (see list of references). Since this paper was first written, maps of parts of the Musgrave Ranges (1 inch = 4 miles) have been published (1955) by the Geological Survey of South Australia.

## NOMENCLATURE

The classification used by Hatch, Wells and Wells (1949) is here largely adopted. In addition, a prefix to the general name "granite", or to a more specific name (e.g., adamellite) is also used, thus—hypersthene adamellite. The prefix "micro" denotes a medium-grained rock (thus, micro-adamellite).

The term *"charnockitic granite"* is used here to draw attention to the fact that some of these granites show important similarities to the charnockitic rocks of the type locality in Madras, India. The term has almost outlived its usefulness.

Rocks of charnockitic type normally are very dark greasy bluish grey or greenish grey, medium-grained and coarse-grained rocks with xenomorphic texture ranging (in composition) from granite through norite to pyroxenite, and characterized throughout by the presence of orthopyroxene.

For purposes of general description the charnockites may be referred to as acid, intermediate, basic and ultramafic in much the same way that igneous rocks have been subdivided by Hatch, Wells and Wells (1949, p. 181). For further details of characteristics of the acid and intermediate charnockites the reader is referred to Holland (1900), Washington (1916), or Pichamuthu (1953).

In the type areas of India it would appear that the charnockites (originally considered to be igneous rocks) are rocks of diverse types (igneous and metamorphic) which have suffered more than one metamorphism. The metamorphism which has produced the charnockitic rocks has produced at the same time khondalites and other rocks which belong to the granulite facies. In Western Australia charnockitic basic rocks appear to have formed in four different environments (Wilson, 1958b).

SOME MAJOR GEOLOGICAL STRUCTURES
OF THE
MUSGRAVE AND AYERS RANGES

LEGEND

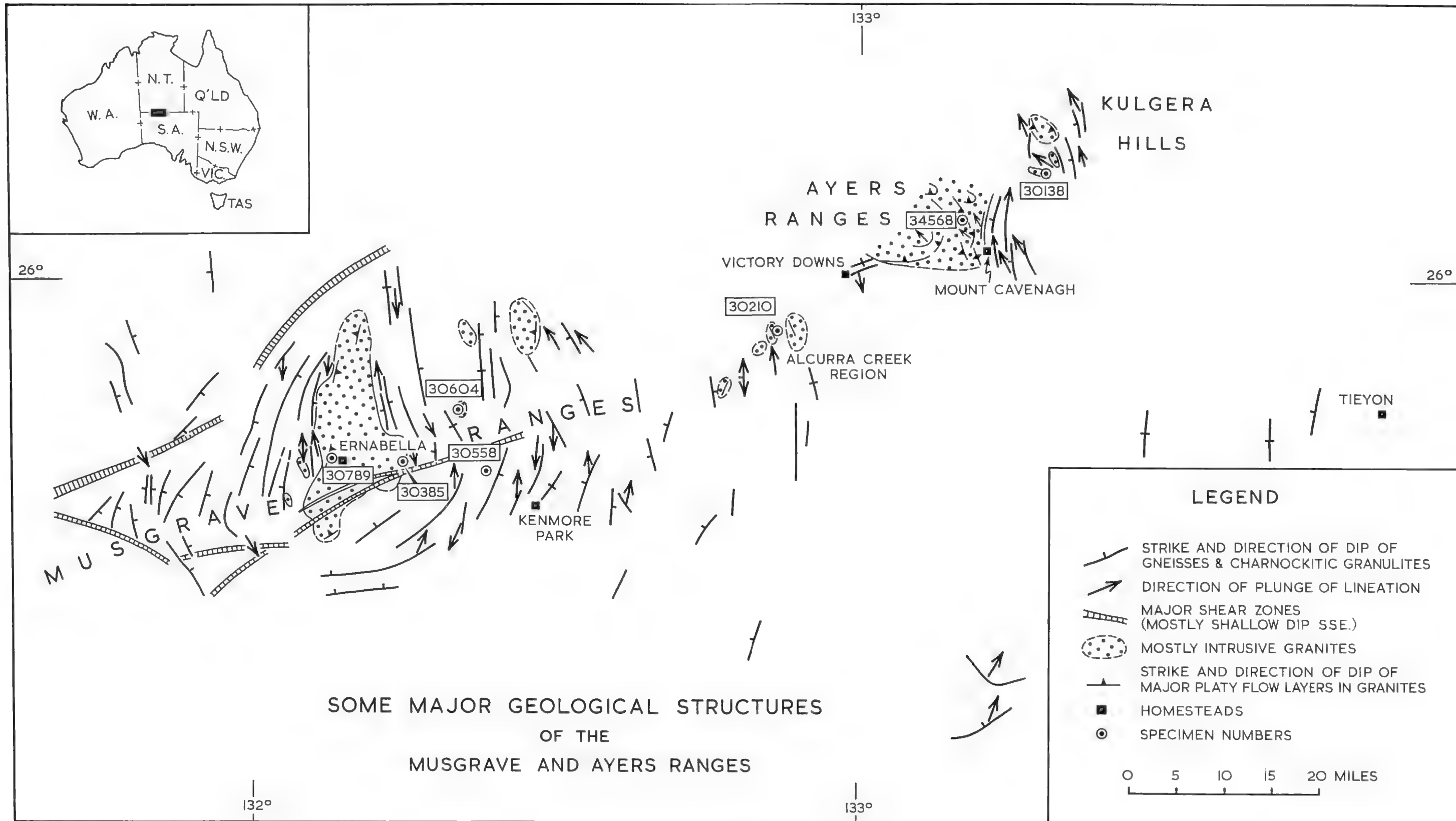| | STRIKE AND DIRECTION OF DIP OF GNEISSES & CHARNOCKITIC GRANULITES |
| | DIRECTION OF PLUNGE OF LINEATION |
| | MAJOR SHEAR ZONES (MOSTLY SHALLOW DIP SSE.) |
| | MOSTLY INTRUSIVE GRANITES |
| | STRIKE AND DIRECTION OF DIP OF MAJOR PLATY FLOW LAYERS IN GRANITES |
| | HOMESTEADS |
| | SPECIMEN NUMBERS |

0    5    10    15    20 MILES

Fig. 1

## GENERAL FIELD CHARACTERS AND STRUCTURE
### MAPS

A map showing the distribution of the major rock types, as known after my first two expeditions into the Musgrave Ranges, has already been published (Wilson, 1947b).

During two subsequent expeditions several weeks were spent re-studying restricted areas and mapping certain new areas in reconnaissance. In the absence of air-photographs, only a reconnaissance map, showing strike and dip of the banding, and lineation of the basement rocks (the gneisses and granulites) and the contacts of the main intrusive masses, has been prepared.[*]

The attitude of dolerite dykes is not shown, but some dykes are plotted on a previous map (Wilson, 1947b), and others appear on the new maps published by the South Australian Mines Department. Another area of about 400 square miles (the Ayers Ranges and Kulgera Hills) has been mapped in reconnaissance with the assistance of air photographs used in the field. This area will be described in detail in later papers.

### THE GNEISSES AND GRANULITES

The oldest rocks in the area are gneisses and granulites in which banding appears to be parallel to bedding planes of original sedimentary rocks. Detailed petrological and structural descriptions of these rocks appear elsewhere (Wilson, 1954b, vol. 2).

Fig. 1 shows that the trend of banding or foliation (= bedding) is roughly meridional for about 150 miles across the strike, i.e. throughout the central and eastern Musgrave Ranges. In many places the gneisses have been thrown into folds, many of which are tight, and all of which are ornamented with minor folds. The trend of the fold axes, and of a lineation is also sub-meridional. There can scarcely be any doubt that the tectonic strike of the original metamorphic rocks of the central and eastern Musgrave Ranges is sub-meridional (Wilson, 1953b, 1954a, and 1954b, vol. 2).

In the Ayers Ranges (particularly in the eastern half) the gneisses are folded on sub-meridional axes, and the lineation is sub-parallel to the fold axes. In the Kulgera Hills the tectonic trend (as shown by tight fold axes and lineation, and average strike-trends) is 330 deg. to 340 deg.

The basement rocks of the Musgrave Ranges are mostly of granulite facies, but many of those of the eastern portion of the Ayers Ranges and all of those of the Kulgera Hills are typical of higher levels of the amphibolite facies.

### THE ORTHOPYROXENE-BEARING GRANITES OF THE MUSGRAVE RANGES
#### (including the Ernabella Adamellite)

The shape of the largest granite mass, which has been called the *Ernabella Adamellite*, is shown in Fig. 7. (For a more detailed map showing actual hills and extent of sand cover, see Wilson, 1947b.) In the Ernabella and Alalka regions it is meridionally-trending, and seems to occupy the axis of a south-plunging synclinorium in the granulites. Notwithstanding its position within a synclinal structure the granite rarely shows truly concordant contacts (Pl. 1, Fig. 1). Wherever studied, the transgressive contacts are marked by xenoliths

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[*] Air-photograph mosaics of the Musgrave Ranges were kindly forwarded by the South Australian Mines Department in 1954 but they arrived too late to allow any significant additions to the map to be made. Subsequently, the Mines Department has published geological maps of part of the Musgrave Ranges based on the use of these air-photographs in the field, but these are also of reconnaissance type, for the gneissic complex has not been systematically subdivided. My map is published as completed in 1954, for it shows many features not included in the maps of the Mines Department (and vice versa).

containing hornblende and biotite. The xenoliths are so alined as to demonstrate that the granite has moved into its present position. Angular xenoliths freshly broken from the wall rocks have been found. Xenoliths are best seen near Harris Springs in the vicinity of Mt. Carruthers, and at the Alalka rock-holes.

In the *Alalka* region (see p. 46) not only are flow-banding and corroded xenoliths of the country rocks alined parallel to the sharp transgressive contacts, but a marked decrease in grain-size is evident close to the contact (Pl. 1, Fig. 2). The gneisses and granulites of the wall rocks have been rendered garnetiferous by the intrusion.

At the eastern contact just N. of Aeroplane Well the granite shows some metasomatic action on the granulites, but this is not a feature of the granite as a whole. The contacts are usually sharp and distinct.

Near *Tjatja*, about 5½ miles S. of Ernabella, the granite mass appears to swing in trend toward the SW. Insufficient field work has been done to say whether or not this granite is related to the somewhat sheared granites said to occur between Upsan Downs and Possum Well (which is 5 or 6 miles S. of Upsan Downs).

Notwithstanding the presence of xenoliths near the main contacts, and a weak alinement of rare plagioclase phenocrysts and mafic clots, these granites are so massive that in many places no reliable structural data could be obtained. The overall dark greasy appearance of the rocks in field and hand-specimen greatly hinders a macroscopic structural study. Such data as are available, however, suggest that the intrusion is similar to several in the Ayers Ranges and Kulgera Hills, where the granites tend to occupy synclinal positions in the gneisses. These granites, however, do not seem to be true phacoliths, for the flow-layers, which are fairly shallow and dip into the intrusion near the edges, steepen to almost vertical near the axis of the elongate structures (see Fig. 2). Although the structure is fairly clear in the Ayers Ranges and Kulgera Hills, it is unwise to assume that the available data are sufficient to prove a similar structure for the Ernabella Adamellite.

The occurrence in the *Koli Koli* and *Tjakunja* regions of outcrops of rocks almost identical with the Ernabella Adamellite is difficult to explain. The assumption that they are cupolas on a granite mass upon which the gneisses "float" is too great an extrapolation of the scanty field data. There is very strong evidence, however, that the granite of the *Harris Springs* area, which underlies the gneisses to the west, re-appears in the valley to the east of the Koli Koli ridge. In this area a hypothesis somewhat similar to that put forward for the Kakamas charnockitic adamellite should be tested in the field. (This has not yet been possible; field work in this area was done in 1944.) At Kakamas the adamellite (which petrographically is somewhat similar to the Ernabella Adamellite) occurs as a sheet which "generally occupies the synclinal troughs of the folded terrain, while the crest of the anticlines form ridges within the intrusion. 'False windows' of older rocks are a conspicuous feature throughout the sheet. Contacts with the associated rocks often transgress across the foliation at a low angle, but both non-transgressive and highly-transgressive contacts are also observed . . . . It is thought that the magma spread out along the synclines of the folded terrain . . ." (Poldervaart and von Backström, 1949, p. 483).

The development of some such hypothesis may throw light on the problem in Central Australia where there is the apparent contradiction of a long E.-W. string of petrologically closely related magmatic granites, many of which form N.-S. bodies sub-parallel to the major fold structures of the basement rocks.

In the *Sentinel Hill* region (see p. 49) the trend of the granite intrusions

and associated granulites to the west is approximately meridional, but the gneisses and granulites to the east have a north-west tectonic trend. In this region the granite is orthopyroxene-bearing in most parts, but coarser hornblende facies are common. In the nearby Bald Hill, and elsewhere, the rocks are devoid of orthopyroxene, yet on petrographic evidence should be considered "co-magmatic" with the orthopyroxenic rocks.

### THE CLINOPYROXENE-BEARING AND HORNBLENDE-BEARING GRANITES OF THE AYERS RANGES AND EASTERN OUTLIERS OF THE MUSGRAVE RANGES

In the *Alcurra Creek Region* a group of low hills of coarse granite appears to form petrographic and geographic links between the orthopyroxene-bearing granites of the Musgrave Ranges to the west and the hornblende-rich granites of the Ayers Ranges to the east. A structural link between the two ranges, however, is not so obvious. No attempt has been made to map this area of poor outcrop. Reconnaissance, however, has shown that contacts with the gneisses are rare. The available evidence (see p. 51) is that the granites have been emplaced as a (palingenetic) magma into meridionally-trending gneisses and granulites. Flow-structures are very weak except near contacts. The general trend of platy-flow layers appears to be between 325 deg. and 335 deg. Although random recording of platy-flow layers may be dangerous and misleading, it seems significant that platy-flow layers which trend E.-W. have not yet been found. It would appear, then, that if the granites of the Musgrave and Ayers Ranges are related, they are linked in a much more complicated fashion than by a "normal" elongate mass of granite which extends westward from the Ayers Ranges through the Musgrave Ranges, and beyond.

In the *Ayers Ranges* the structure of the granite is more easily mapped, for although xenoliths are uncommon, platy-flow layers are revealed in most places by the alinement of large K-feldspar phenocrysts. With the aid of air photographs the greater part of the Ayers Ranges was mapped in reconnaissance. Only the main structural features are mentioned in this paper.

As shown on Fig. 1, the main granite mass lies west and north-west of Mt. Cavenagh Homestead, whereas to the east major and minor folds and lineation in the gneisses are approximately meridional in trend. The southern contact with the gneisses was not mapped, but near Victory Downs Homestead (which lies close to the WSW contact of the main outcrops of the granite of the Ayers Ranges) the gneisses strike E.-W., and are meridionally lineated. The attitude of the flow-layers of the granite shows what may be considered to be a large curved structure, crescent-shaped in plan with shallow plunge in a north-westerly direction.

The structures of the granite are sub-concordant with garnetized gneisses on parts of the eastern side of the intrusion. Within the granite area no gneiss has been found, but some may be covered by the sand through which the more resistant hills of granite protrude. The flow-structures of some of the hills (such as Mt. Reynolds, and a smaller hill 3 miles to the west) show that the mode of emplacement of the granite was complicated within the main granite area. In these hills the flow-structure presents the picture of a synclinal granite body, closed on the eastern end and plunging at a low angle to the west. These granite bodies can scarcely be phacoliths, however, for on the western end, where subhorizontal flow-layers could be expected to complete the synclinal structure, there are vertical or steep dips. A similar structure on a small scale was more closely mapped in the Kulgera Hills, some 10 miles ENE. of Mt. Reynolds (see Fig. 2). It appears that structural weaknesses in the basement
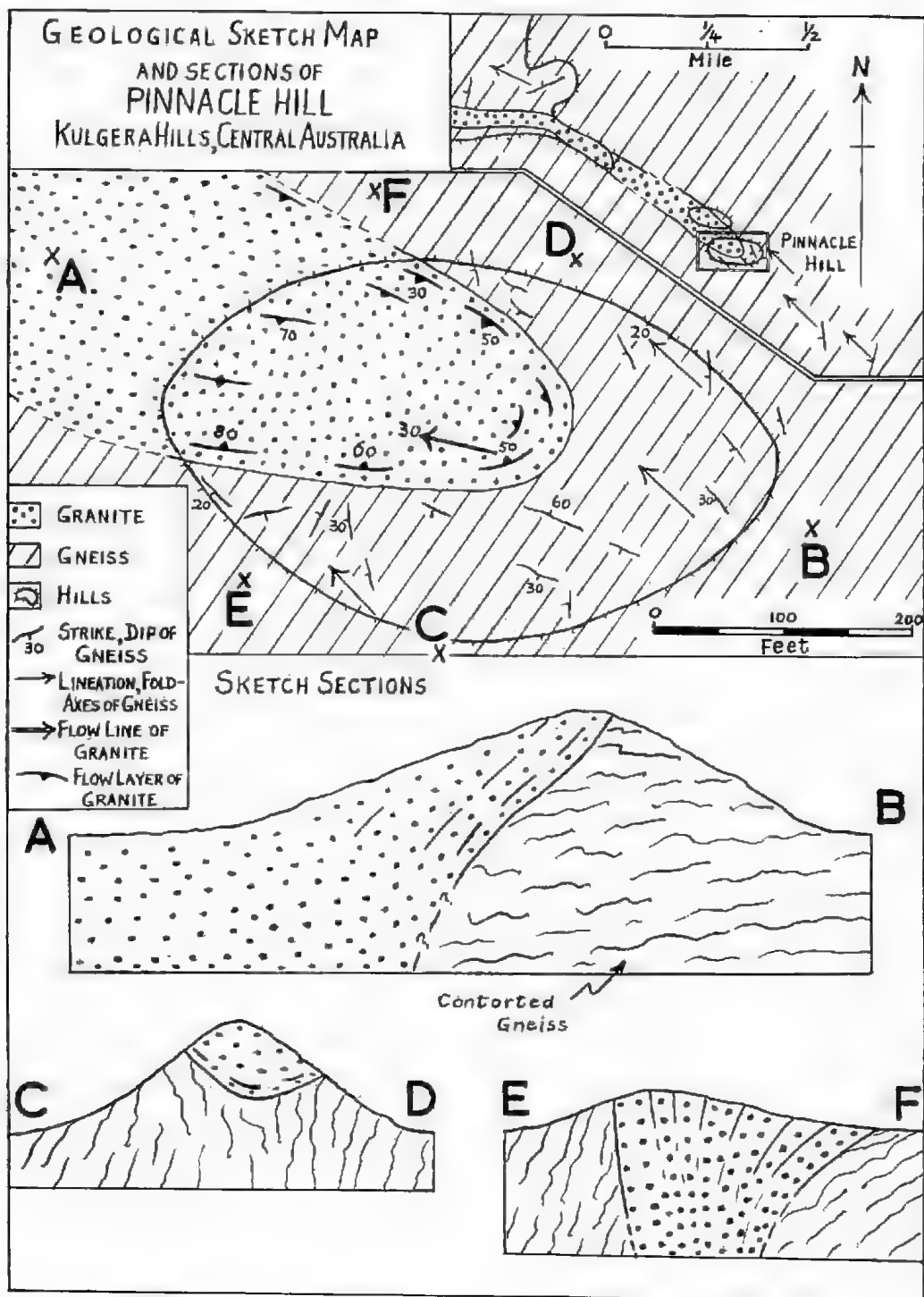
Fig. 2.—Geological sketch map and sections of Pinnacle Hill, Kulgera Hills, Central Australia.

rocks (faults or fold-axial "planes") have been utilized by upsurging palingenetic magma. Insofar as it remains within old synclinal structures, the outer flow-structures appear to delineate a syncline, but the "feeder dyke", situated nearer the axial "plane" of the fold, may well be steeply-dipping. By analogy with the Kulgera Hills, it is concluded that gneisses may lie buried at shallow depths beneath the sand from which protrude the more resistant granite masses.

The *Kulgera Hills* are separated from the Ayers Ranges by a westerly-trending trough in which (?) Mesozoic sediments are the only outcrops. The granites of Kulgera Hills themselves may be considered to lie about 15 miles NE. of the main granite area of the Ayers Ranges. Since a large manuscript describing the geology of the region is awaiting publication, only a few of the major structural features will be mentioned here.

Study of platy-flow and linear-flow structures in the granites indicates that, notwithstanding marked local transgressive structures, the general trend of the granite intrusions is sub-parallel to the fold axes and lineation of the gneisses, i.e., 330 deg. to 340 deg.

The most instructive granite intrusion is that seen at The Pinnacle, a small pointed hill two miles E. of Kulgera Homestead. In Fig. 2 the main structural features are shown. The Pinnacle is the end of a granite body similar to some of those in the Ayers Ranges. The contact with the contorted gneisses is sharp and feldspathized only in places. It dips inwards on the S., E. and N. contacts, but near the middle of the structure the flow-layers are vertical. On top of the hill the bottom contact (which is here also the E. contact) is found to dip about 30 deg. to the WNW. This dip is also the plunge of elongate plagioclase phenocrysts, and represents the plunge of the linear-flow of the intrusion at that point. On top of the hill, although the intrusion is synclinal, the contorted meta-sediments are not conformable with the intrusion. As one proceeds WNW. along the "axis" of the structure the plunge appears to steepen, but the platy-flow layers rapidly steepen. At the bottom of the hill both granite contacts dip into the granite but near the middle of the structure the dip of the flow layers is vertical, not horizontal as would be expected if the body were synclinal (see Fig. 2, E-F). The granite body takes on the appearance of a wide, steeply-dipping dyke as it is traced ENE. along the strike.

It thus appear that the intrusion at The Pinnacle is really a special type of dyke. The magma (which has given rise to a rock very similar to the Kulgera Adamellite) has been forcibly injected up shears sub-parallel to the regional structure, and in favourable structural positions has formed tension-controlled gashes which are crescent-shaped in plan. The other granite masses of the area appear to be of similar type. Microfacies of the main granite, and pegmatites, occur in the gneisses, especially near the contacts of coarse granite and gneiss.

## PETROGRAPHY

### ORTHOPYROXENE-BEARING GRANITES

#### ERNABELLA REGION

In an earlier paper (Wilson, 1947b, p. 206) the belief was expressed that these rocks are probably mostly granodioritic in composition. Since subsequent work has shown that in this region adamellite is more common than granodiorite, the name *Ernabella Adamellite* is thought to be suitable as a general term of reference, notwithstanding the fact that the only available chemical analysis from the immediate vicinity of Ernabella was carried out on a rock which has

been found to lie between adamellite and granodiorite in composition. Two related orthopyroxenic granites from the Musgrave Ranges are adamellites, according to chemical analyses (Table 2).

*Ferrohypersthene granodiorite* (close to adamellite) (30789).°—Collected quarter mile due west of Ernabella water-hole; typical of granitic rocks in vicinity; no primary planar or linear flow structures noticed in the field (Fig. 7).

In hand-specimen: massive coarse-grained greasy bluish dark grey rock composed of bluish grey feldspars, small bluish grey glassy quartz irregularly distributed, and small ragged clots of greasy dark brown mafic minerals; dark nature of rock renders mafic minerals less conspicuous; rare pyrite; plagioclase commonly shows albite-twins, and K-feldspar commonly contains numerous small round inclusions of quartz; phenocrysts of plagioclase rare, but one well-twinned crystal measuring 40 mm × 12 mm was found; common accessory zircon fluoresces yellow; weathering commonly deeply penetrates boulders, rendering collection of fresh material very difficult; tendency for uniform discolouration to resinous brown very deceptive – compare the "Brown Granites" of Mozambique (Assuncao and Pinto Coelho, 1955).

In thin-section: xenomorphic granular, with mafic minerals and quartz in smaller grains than feldspars; average grain-size between 1·5 mm and 2 mm (see Pl. 2, Figs. 3 and 4).

Plagioclase (49%) — andesine, An 39, non-zoned; anhedral, mostly 2 mm diam., well-twinned on albite-pericline laws, but development of twinning appears related to warping and shattering of many grains; corroded on large scale by K-feldspar especially where shearing has developed weaknesses in grains, weakly micro-antiperthitic, with irregular inclusions of K-feldspar apparently produced by K-feldspar corrosion rather than exsolution (Pl. 2, Fig. 3), inclusions of sagenitic rutile common, and clouds of squat rutile rods and distorted magnetite octahedra in some grains; apatite and zircon crystals in some K-feldspar inclusions; quartz inclusions negligible; extinction = 20 deg.

K-feldspar (24%)—orthoclase microperthite partly inverted to microcline as shown by incipient shadowy cross-hatch extinction on (001), and large negative optic axial angle (about 80 deg.); mostly 2 mm diam.; moderately microperthitic; round quartz inclusions about 0·2 mm diam.; corrodes plagioclase, and thus occurs as small irregular patches of micro-antiperthite in plagioclase; needle inclusions very rare, smudges of iron ore dust plentiful.

Quartz (15%) – mostly ragged grains 1 mm diam.; also small corroded round grains ("millet seed" type) about 0·2 mm diam. in K-feldspar (Pl. 2, Fig. 4); needle inclusions rare, smudges of iron ore dust and bubbles plentiful; somewhat shadowy extinction.

Orthopyroxene (4%) – ferrohypersthene, Fe 64%, non-zoned; rounded anhedral; mostly 0·8 mm × 0·4 mm, commonly as core of irregular mafic clots which are mostly 2 mm × 1 mm (but up to 20 mm × 10 mm, as seen in hand-specimen), and in which it is closely associated with clinopyroxene, iron ores, apatite and zircon; fine lamellar structure (including some narrow clinopyroxene exsolution lamellae) // optic plane (010); lamellae commonly bent and fractured as in plagioclase, but clinopyroxene which is occasionally found corrod-

ing orthopyroxene shows no evidence of such (?) protoclastic structures; alters along irregular cracks and poor cleavages to dull light brown chloritic matter, whereas associated clinopyroxene tends to remain unaltered; pleochroism weak — pale pinkish fawn, pale fawn, very pale greenish grey; $\lambda - 1.745$; $2V/\alpha = 59°$; dispersion $v > r$, moderate.

Iron Ores $(3.5\%)$ — apparently ilmenite and magnetite equally represented, together with a few grains of pyrite; anhedral masses, about $0.3$ mm diam., mostly associated with orthopyroxene, apatite and zircon in mafic clots; several grains corroded by hornblende or biotite; also, tiny distorted octahedra of magnetite and iron ore dust in several larger plagioclase grains.

Clinopyroxene $(2\%)$ — calcic augite, Ca40½ Mg32½ Fe27, non-zoned; anhedral grains mostly $0.4$ mm diam.; commonly as groups of two or three grains associated with iron ores, or as irregular grains adjoining (and in some cases apparently corroding) orthopyroxene; clear, unaltered and exceedingly weakly pleochroic (or not at all) in very pale greenish greys; (110) cleavage, prominent partings // (100) and (001), and less prominent // (010); cleavage and parting surfaces not bent and fractured as are those of associated orthopyroxene; narrow pyroxene lamellae // (100); $\lambda - 1.726$; $2V/\gamma = 51° \pm 1°$; $\gamma \wedge c - 42°$.

Apatite $(1.5\%)$ — squat subhedral colourless grains (commonly $0.15$ mm $\times$ $0.1$ mm) mostly associated with iron ores, zircon and hypersthene in mafic clots, or as elongate euhedral grains associated with K-feldspar inclusions in plagioclase; non-fluorescent; tubular inclusions // $c$; $\omega = 1.635$, indicating fluor-apatite.

Hornblende $(0.5\%)$ — mostly small irregular anhedral grains (with rare patches up to 3 mm $\times$ $1.5$ mm) corroding iron ores; associated blebs of clear quartz may be derived from transformed pyroxene; unaltered non-sheared, clear; pleochroism strong — fawn, dark khaki-brown, greenish khaki; $\lambda = 1.701$.

Zircon $(0.5\%)$ — mostly very pale pink euhedral crystals up to $0.3$ mm $\times$ $0.2$ mm, and usually associated with apatite and iron ores; yellow fluorescence.

Biotite — rare ragged flakes adjoining iron ores; pleochroism, light straw-yellow, chestnut-brown.

Calcite — very rare alteration product of plagioclase.

A *chemical analysis, norm* and *mode* of this rock are set out as 10 in Table 3, and also in Table 2, *ion percentages* are set out in Table 4, and further reference is made in Figs. 4 and 6. Discussion of these data is reserved for the petrogenesis section.

*Ferrohypersthene adamellite*—(30846).—Within a few feet of the summit of Mt. Carruthers, a prominent landmark $1.5$ miles W. of Ernabella, and $0.4$ mile from the intrusive contact with the gneisses and granulites; similar to 30789, but a more normal adamellite, and orthopyroxene much less ferriferous, exsolution lamellae of clinopyroxene coarse, and there are no large plagioclase phenocrysts. See Table 1.

*Ferrohypersthene microadamellite* (close to adamellite)—(30871).—At the mouth of a gorge 2 miles WSW. of Ernabella, and $1.4$ miles SSW. of Mt. Carruthers; not far from basement granulites; considerably finer grain-size than most of the hypersthene granites of the area (feldspars average $0.6$ mm diam., pyroxenes average $0.2$ mm diam.); textures and mineral relations as for 30789, but plagioclase more micro-antiperthitic than in 30789; although pyroxenes contain corroded masses of iron ore, and the rock contains more iron ore (11 per cent.) than any other granite so far studied from the area, several rocks in Musgrave Ranges contain more ferriferous pyroxenes; iron ore also plentiful as irregular plates "healing" shears and gashes in most minerals. See Table 1.

*Ferrohypersthene adamellite*—(30658).—About half-way down the SW. side of the prominent hill 3 miles NNE. of Ernabella; probably typical of consider-

able portions of the group of hills about 4 miles NNE. of Ernabella, although amphibole-bearing variants may be present among some of the coarser-grained rocks in the area; although finer in grain-size, textures and mineral relations as in 30789; calcite, apparently of late magmatic origin, as small irregular patches mostly associated with biotite and rare chlorite. See Table 1.

### ALALKA REGION

The largest masses of the Ernabella Adamellite are developed in the Alalka region, about ten miles N. of Ernabella (Fig. 7). Where contacts were studied (e.g., at the Alalka rock-holes, and at Razor Hill) there is very good evidence of the magmatic emplacement of the Ernabella Adamellite. A typical contact near Alalka is shown in Pl. 1, Fig. 2. Not only are flow-banding and corroded xenoliths of the country rocks alined parallel to the sharp transgressive contact, but a marked decrease in grain-size is evident close to the contact. The gneisses and granulites of the wall rocks have been rendered garnetiferous by the intrusion.

*Ferrohypersthene granodiorite* (close to adamellite)–(30476).–Near the contact with granulites 2½ miles NNW. of Alalka rock-hole and 3 miles SE. of Wardulka rock-hole, and also only a few yards from a small olivine dolerite dyke; fawn in colour due to superficial weathering; dull dark brown mafic clots only faintly oriented; texture and mineral relationships as for 30789, but mafic clots somewhat more prominent, magnetite in the form of in-fillings of cracks more common, quartz sagenitic and with tendency to be flattened parallel to weakly developed streakiness of mafic clots (Pl. 2, Figs. 1 and 2). See Table 1.

### TJATJA-OMBAGUNDA REGION

The map (Fig. 7) shows that the Ernabella Adamellite, as developed in the Tjatja area, continues ENE. into the Ombagunda area. Mt. Ferdinand, however, which is midway between the two areas, is composed of banded acidic pyroxene granulites. It is not known whether there is any visible link between the igneous rocks of the two areas. To the south of Mt. Ferdinand most of the rocks appear to be gneisses and granulites.

*Ferrohypersthene adamellite*–(30385).–Typical of the granitic rocks about one mile SSE. of Ombagunda Well where they inject the acid pyroxene granulites which make up the basement rocks of large parts of the eastern Musgrave Ranges; collected about 20 yards S. of the junction of a norite dyke which cuts the granite; dull greasy brown, typical of incipient weathering of an iron-rich rock.

In thin-section: similar to 30789 (p. 44) in texture and mineral relations, but with following differences: mafic minerals notably less ferriferous and not so obviously in clots: K-feldspar more microperthitic, and closely associated with grotesquely poikilitic hornblende (pleochroism–fawn, brown, greenish khaki) and clear vermiform quartz where plagioclase is corroded; quartz mostly as sagenitic "millet seed" inclusions 0·35 mm diam. in K-feldspar, apatite murky light grey due to acicular inclusions // c; zircon pale fawn with dusty inclusions. Details of mineral compositions are set out in Table 1.

A *chemical analysis, norm* and *mode* of this rock are set out as 6 in Table 3, and also in Table 2, *ion percentages* are set out in Table 6, and further reference is made in Figs. 4 and 6. A discussion of these data is reserved for the petrogenesis section.

### TJAKUNJA REGION

On the ENE. side of the prominent mountain, Tjakunja (about 9 miles NW. of Ernabella), and a few hundred yards N. at a small pinnacle-shaped hill,

## TABLE 1

### Modal and Mineralogic Data of Granites from Central Australia.

| | | 30789* | 30816 | 30871 | 30653 | 30476 | 30385* | 30700 | 3070L | 30558* | 30504* | 30573 | 30210* | 34568* | 30138* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Quartz | Vol. % | 15 | 15 | 24 | 17.5 | 17 | 23 | 20 | 17 | 20 | 27 | 37 | 21 | 19.7 | 24 |
| K-feldspar | Vol. % | 24 | 35 | 21 | 21 | 21 | 27 | 30 | 20 | 38 | 21 | 43 | 23 | 24 | 24 |
| Plagioclase | Vol. % | 49 | 37 | 28 | 33 | 45 | 37 | 20 | 46 | 23 | 37 | .0 | 41 | 41 | 37 |
| | Compos., Mol. % An | 39 | 40 | 37 | 34 | 41 | 34 | 37 | 36 | 29 | 37 | 23 | 32 | 35 | 26 |
| | Extin., ⊥ α, α′ Λ 010 | 20 | 21 | 19 | 16 | 22 | 16 | 19 | 18 | 11 | 19 | 10 | 14 | 17 | 7.5 |
| Orthopyroxene | Vol. % | 4 | 6 | 8 | 7.5 | 6 | 4 | 9 | 2 | 4 | nil | nil | nil | nil | nil |
| | Compos., Mol. % Fe | 64½ | 55 | 62 | 62½ | 52 | 50 | 65½ | | 56½ | | | | | |
| | 2V (-) | 1·745 | 1·733 | 1·729 | 1·742 | 1·729 | 1·727 | 1·746 | | 1·735 | | | | | |
| | | 59 | 54 | | 58 | 51 | 52 | | | | | | | | |
| Clinopyroxene | Vol. % | 2 | 2 | 5 | 4.5 | 4 | 3 | 5 | 3 | 3 | 1 | | 3.5 | 1.3 | |
| | Compos., Mol. % Ca/Mg/Fe | 40½ 32½ 27 | 43 33 24 | 42 33½ 24½ | 40½ 20½ 20 | 43 35½ 21½ | 38 42½ 24 | 39 29 32 | | 40½ 33 26½ | | | 43 35½ 21½ | | |
| | 2V(+) | 1·720 | 1·723 | 1·723 | 1·729 | 1·720 | β—1·699 | 1·730 | 61 | 1·725 | | | 1·720 | β—1·699 | |
| | Extin., γΛc | 51 42 | 58 43 | 52 | 52 | 53 | 47 45 | 51 43 | | 51 45 | | | 58 43 | | |
| Hornblende | Vol. % | 0·5 | tr | nil | 4.5 | tr | 1 | 1 | nil | 3 | 7 | 1 | 4.5 | 5.5 | 1.5 |
| | 2V(-) | 1·701 | | | 1·703 | | 1·685 | 1·695 | | 1·686 | 1·682 | 1·688 | 1·681 | 1·673 | 1·692 |
| | Extin., γΛc | 75 15 | | | 74 | | 78 19 | 75 | | 72 | 78 18 | | 71 18 | 75 17 | 55 19 |
| Biotite | Vol. % | tr | tr | 1·5 | 2 | tr | tr | tr | tr | tr | 0.1 | 4 | 0.5 | 0.4 | 5·5 |
| | 2V( ) | | | 1·818 | 1·805 | | 1·617 | | | 1·641 | 1·628 | 1·020 | 1·617 | 1·616 | 1·680 |
| | | | | 10 | 10 | | 0 | | | 5 | 10 to 15 | 0 to 5 | 5 to 10 | 5 to 10 | 0 |
| Iron Ores | Vol. % | 3.5 | 4.2 | 11 | 6.5 | 5 | 4 | 5 | 3 | 4 | 5 | 2 | 4 | 3.9 | 3.5 |
| Apatite | Vol. % | 1.5 | 1.5 | 1 | 2.5 | 1 | 1 | 3 | 2 | 0.5 | 1.6 | 0.5 | 1.5 | 1.9 | 1.2 |
| | α | 1·636 | | 1·635 | | 1·636 | 1·637 | 1·635 | | 1·638 | 1·636 | | 1·637 | | 1·636 |
| Zircon | Vol. % | 0.5 | 0.3 | 0.5 | 0.5 | 0.5 | tr | 1 | 0.5 | 0.3 | 0.3 | 0.3 | tr | 0.3 | 0.3 |
| Calcite | Vol. % | tr | | tr | 0.5 | | | tr | tr | tr | nil | tr | | | |
| Sphene | Vol. % | nil | nil | nil | nil | nil | nil | nil | nil | nil | nil | 2.5 | tr | | 3 |

*For chemical analysis, see Table 2.

30789. Ferrohypersthene granodiorite, Ernabella, Musgrave Ranges.
30816. Ferrohypersthene adamellite, Mt. Carruthers, Musgrave Ranges.
30871. Ferrohypersthene microadamellite, 2 miles W¾W. of Ernabella, Musgrave Ranges.
30658. Ferrohypersthene adamellite, 3 miles NNE. of Ernabella, Musgrave Ranges.
30476. Ferrohypersthene granodiorite, 2¼ miles N½W. of Alalka, Musgrave Ranges.
30385. Ferrohypersthene adamellite, Ombengunda, Musgrave Ranges.
30700. Ferrohypersthene adamellite, near Tjakuuja, Musgrave Ranges.
30701. Ferrohypersthene adamellite, Tjakuuja, Musgrave Ranges.
30558. Ferrohypersthene adamellite, Spinifex Hill, Musgrave Ranges.
30604. Hornblende adamellite, near Bald Hill, Musgrave Ranges.
30573. Hornblende-sphene–biotite alkali-granite, Stony-Innop-Up, 11 miles E. of Ernabella, Musgrave Ranges.
30210. Augite-hornblende adamellite, Alcurp Creek, E. Musgrave Ranges.
34568. Hornblende adamellite, 3½ miles NW. Mt. Cavenagh homestead, Ayers Ranges.
30138. Hornblende-biotite adamellite, Kulgera Hill, Kulgera Hills.

greasy bluish-grey ferrohypersthene adamellites occur as intrusions into acid hypersthene granulites (Fig. 7). When the W. face was visited in 1944 it seemed that the whole of Tjakunja was charnockitic gneiss, and it was mapped as such. In 1949, a traverse from Alalka ended at Tjakunja, and it was then that the igneous rock so common in the Ernabella area was found to be present (but inconspicuous) near the ENE. base of the mountain. About one mile across the plain to the E., a minor intrusion of hypersthene adamellite of the type developed at Wardulka makes a well-marked transgressive and intrusive contact with the acid hypersthene granulites. No other "magmatic" hypersthene granitic rocks are known from this region, but in view of the lack of detailed study of the mountains to the SE. of Tjakunja some may exist there and thus provide a link with the Ernabella region.

*Ferrohypersthene adamellite*—(30700).—SE. side of the small pinnacle near the NE. of Tjakunja; identical in appearance, and similar in texture and mineral relations, to 30789, but with the following differences: plentiful grotesque masses of micro-antiperthite produced by intimate corrosion by K-feldspar (Pl. 4, Fig. 1), but such replacement most obvious where andesine grains shattered and bent and where twinning best developed; andesine inclusions in hypersthene not antiperthitic, tending to confirm that the antiperthite is result of corrosion of plagioclase by K-feldspar rather than of exsolution of K-feldspar from plagioclase; pyroxenes most ferrous yet recorded in Musgrave Ranges. Details of mineral composition are set out in Table 1.

*Ferrohypersthene adamellite* (close to granodiorite)—(30701).—ENE. side of Tjakunja; mineral composition identical, and mineral relations similar to 30700 but with the following differences: although andesine heavily corroded by K-feldspar, the micro-antiperthite so formed is not as grotesque in appearance (cf. Pl. 3, Figs. 1 and 2, Pl. 4, Fig. 1); in 30700 the K-feldspar is microperthitic except where it occurs as filaments and impregnating bands in the andesine, but in 30701 the impregnating K-feldspar itself is very finely perthitic (Pl. 3, Figs. 1 and 2).

### SPINIFEX HILL REGION

A small mass of ferrohypersthene adamellite appears to inject the submeridionally-trending gneisses and granulite of Spinifex Hill, a prominent hill about 6 miles NW. of Kenmore Park homestead (Fig. 7). No time was available to make a structural survey of the hill, but its relative ease of access and excellent outcrops should encourage detailed study.

*Ferrohypersthene adamellite*—(30558).—Near the summit of Spinifex Hill; medium- to coarse-grained fresh greasy dark grey massive rock composed of dark-coloured feldspars and quartz, and subordinate greasy clots of mafic minerals; in thin-section, minerals roughly oriented, and quartz somewhat elongate as is quartz of basement granulites; features linking this rock more with Ernabella Adamellite than with the (older) basement granulites are apparent intrusive relations, typical and distinctive "charnockitic" appearance in hand-specimen, distinctive mineralogy and similar chemical composition; similar to 30789 in texture and mineral relations but with the following differences: oligoclase, much corroded by K-feldspar, irregularly antiperthitic; hornblende sheaths pyroxenes and iron ore; clinopyroxene corrodes orthopyroxene. Details of mineral compositions in Table 1.

A *chemical analysis, norm* and *mode* of this rock are set out as 4 in Table 3, and also in Table 2, *ion percentages* are set out in Table 6, and further reference is made in Figs. 4 and 6. A discussion of these data is reserved for the petrogenesis section.

### SENTINEL HILL REGION

Sentinel Hill (also called Mt. Carnarvon) is a prominent mountain of granite which forms the NE. outpost of the Musgrave Ranges. Fig. 7 shows other granitic hills in the vicinity. Where contacts have been seen the igneous rocks appear to have been emplaced magmatically. The trend of the Sentinel Hill intrusion and of the associated granulites to the W. is meridional, but the gneisses and granulites to the E. have a NW. tectonic trend. The Sentinel Hill and associated intrusions to the NW. were studied in reconnaissance only, but sufficient was done to show that the bulk of the igneous rocks are orthopyroxene-bearing adamellites. Some of the coarser facies, however, are hornblende adamellites, which are devoid of hypersthene, and may only contain a few relics of augite.

One of the most striking features of the orthopyroxene-bearing adamellites of this region is the development of micro-antiperthitic masses by the heavy corrosion of plagioclase by K-feldspar. Moreover, the orthopyroxene is commonly corroded by clinopyroxene. Textural details (illustrated) are set out elsewhere (Wilson, 1954b, Vol. 3).

### CLINOPYROXENE-BEARING AND HORNBLENDE-BEARING GRANITES

Four rocks of this group have been chemically analysed, and show some striking similarities to the three analysed orthopyroxene-bearing granites.

### BALD HILL REGION

Bald Hill is a small prominent bare hill about ¾ mile NE. of Donald Well, which is twelve miles ENE. of Ernabella (Fig. 7). Bald Hill and some of the nearby hillocks are composed of a coarse hornblende adamellite which is cut by rare flat-lying microgranite dykes. The basement rocks, which are cut by these magmatically-emplaced adamellites, are mostly meridionally-trending acid hypersthene granulites and acid hornblende granulites. On the N. side of Tietkin's Creek at Donald Well, however, a remarkably contorted cordierite-sillimanite gneiss (30606) was found. This is the furthest west that this type of rock (which is commonly developed near intrusions of hornblende adamellite in the Kulgera Hills which are 75 miles ENE. of Bald Hill) has been found.

Owing to the difficulty of collecting sufficient fresh rock from Bald Hill itself, the specimen for analysis was taken from a nearby knoll. It is representative of the region.

*Hornblende adamellite* (close to hornblende granodiorite)—(30504).—From a knoll about half-way between Bald Hill and Donald Well, which is about 12 miles ENE. of Ernabella; coarse-grained, composed of fawn-grey feldspars and dull black mafic clots of hornblende and pyroxene, very faintly oriented; rare pale fawn andesine phenocrysts (up to 16 mm long); in thin-section, xenomorphic granular and similar to, but somewhat coarser than the ferro-hypersthene-bearing rocks of comparable chemical composition (e.g., 30789) from Ernabella region; many of same replacement structures and mineral associations appear, but absence of orthopyroxene, rarity of clinopyroxene, and coarse development of hornblende, link the adamellites from Bald Hill with many of those of Ayers Ranges.

*Plagioclase* (37%)—andesine. An 37; non-zoned; up to 9 mm × 4 mm; albite—pericline twin-lamellae cracked and curved; corrosion by K-feldspar not as obvious as in many similar rocks from the Musgrave Ranges (but note: curved and shattered twin-lamellae occur in andesine which is strongly corroded by K-feldspar in almost identical hornblende adamellite (30596) from W. face

of Bald Hill—see Pl. 2, Fig. 5); plentiful inclusions of rutile needles, pink-brownish dust, and some octahedra of magnetite as in some of the ferrohypers-thene granodiorites near Alalka; no lenticular micro-antiperthite inclusions, and only a few ragged patches of corrosive K-feldspar; extinction = 19 deg.

Quartz (27%)—irregular grains 1·5 mm diam., and as round grains 0·5 mm diam. in K-feldspar; non-sagenitic.

Microcline microperthite (21%)—very fine cross-hatch twinning; irregular masses up to 5 mm diam.; corrodes plagioclase to small degree; a few rutile needle-inclusions.

Hornblende (7%)—irregular masses up to 5 mm diam.; encloses iron ore, corroded pyroxene, apatite and zircon; pleochroism—pale fawn, khaki-green, yellowish green; $\gamma = 1\cdot682$; $\gamma \wedge c = 18^\circ \pm 2^\circ$; $2V/\alpha = 73^\circ$.

Iron ores (5%)—mainly as clots in hornblende.

Apatite (1·6%)—in mafic clots, and in plagioclase, especially where K-feldspar has corroded plagioclase; tubular inclusions $//$ $c$; $\omega = 1\cdot636$, indicating fluorapatite.

Clinopyroxene (1%) — similar to calcic augites of Ernabella region; corroded relics in hornblende.

Zircon (0·3%) — mostly in mafic clots; yellow fluorescence.

Biotite (0·1%) — corrodes iron ores; strong pleochroism — fawn, chestnut-brown, yellowish brown; $\gamma = 1\cdot623$; $2V/\alpha = 10^\circ\cdot15^\circ$; dispersion strong, $r < v$.

Sphene and calcite absent.

A *chemical analysis*, *norm* and *mode* of this rock are set out in Table 2, *ion percentages* are set out in Table 6, and further reference is made in Figs. 5 and 6. A discussion of these data is reserved for the petrogenesis section.

## SENTINEL HILL REGION

Although the bulk of the acid intrusions of this region are orthopyroxene-bearing adamellites, some of the coarser facies of these are hornblende adamel-lites devoid of orthopyroxene (see page 49).

They differ in no essential respect from the hornblende adamellite from Bald Hill (30604).

## STONY-JUMP-UP REGION

A large mass of hornblende-sphene-biotite granite forms prominent hills about one mile S. of Stony-Jump-Up about 11 miles E. of Ernabella (Fig. 7). The eastern edge of what appears to be a large shallow-dipping dyke shows well-marked intrusive features, but little is known of the western and southern contacts. Micro-facies of this granite cut the gneisses on the S. side of the Stony-Jump-Up. The intruded rocks of the region are mostly acid hypersthene granulites, but in the vicinity of this non-pyroxenic granite the basement rocks are biotite-hornblende gneisses and granulites which are apparently devoid of hypersthene.

This is the only known granite from the Musgrave Ranges which is devoid of pyroxenes, and contains sphene, biotite and a bluish green hornblende.

*Hornblende-sphene-biotite alkali-granite* — (30573).—About 100 feet W. of the eastern contact of main granite mass about ¾ mile S. of Stony-Jump-Up; pale bluish grey coarse even-grained granite, streaked irregularly with greasy dark brown biotite-rich mafic clots about 20 mm × 5 mm; in thin-section (supplementing Table 1):—microcline microperthite well twinned, abundant; quartz non-sagenitic; oligoclase sagenitic; biotite, pleochroism — very pale straw, dark chocolate; hornblende, pleochroism — dirty yellowish green, deep brownish green, dirty bluish green; sphene corroding iron ores; zircon fluorescent.

THE ALCURRA CREEK REGION

*(previously known as Beefwood Creek Region)*

The Alcurra Creek, a tributary of the Alberga River near its source, rises in a group of low hills which are composed almost wholly of coarse granites of considerable interest (Fig. 1). Although devoid of hypersthene, most of these rocks are clinopyroxene-bearing, and display features which suggest a petrological link between the granites of the Ayers Ranges and the Musgrave Ranges. As these hills have not been mapped, the major structure is unknown. Moreover, most of the individual granite hills probably represent the more resistant portions of a granite and gneiss basement. The gneissic components, have been largely eroded away, are now mostly covered by a thin veneer of sand from which they protrude in favoured positions. The available evidence (best seen on the track about 14 miles SW. of Victory Downs Homestead and 2·5 miles WSW. of Alcurra Creek Crossing) is that the granites of this region have been emplaced as a magma into meridionally-trending gneisses and granulites.

In addition to outcrops near Alcurra Creek, several small granite hills near the Marryat Creek about nine miles SW. of the Alcurra Creek Crossing have been included, for convenience, in the Alcurra Creek region.

*Augite-hornblende adamellite*—(30210).—At 1952 Crossing of Alcurra Creek (Beefwood Creek of earlier publications: Wilson, 1947b, p. 199, and 1950b, p. 230); no contacts with older rocks were found; rare xenoliths of coarse quartzite and amphibolite; approximate trend of a poor flow-structure between 325° and 335°; fairly fresh coarse-grained pinkish fawn homogeneous rock composed of pink plagioclase (up to 15 mm long), light fawn K-feldspar, very light grey vitreous quartz, and non-oriented mafic clots containing shiny black hornblende and greasy dull greenish grey pyroxene.

In thin-section (supplementing Table 1):—andesine—tabular grains, needle and plate inclusions common, patchy development of pinkish dusty inclusions giving andesine pink colour (and fluorescence) in hand-specimen and pale pink colour even in thin-section, grains shattered and twin-lamellae bent, most grains extensively replaced by non-shattered microcline microperthite; quartz—long rutile needles oriented in three directions; hornblende—poikilitic anhedral masses enclosing corroded clinopyroxene and iron ores; pleochroism—fawn, dull khaki-green, grass-green; calcic augite—clear pale greenish non-pleochroic anhedral grains up to 1 mm diam., (100) and (001) lamellae and parting not as common as in calcic augites of Musgrave Ranges even though composition apparently identical, heavily corroded by hornblende; biotite—associated with iron ores, pleochroism—pale straw-yellow, yellowish brown; zircon—fluorescent, and similar to zircon of orthopyroxene granites of Musgrave Ranges (Wilson, 1950b, p. 229); sphene—encrustations on some grains of iron ore. Details of mineral compositions in Table 1.

A *chemical analysis, norm* and *mode* of this rock are set out in Table 2, *ion percentages* are set out in Table 6, and further reference is made in Figs. 5 and 6. A discussion of these data is reserved for the petrogenesis section.

*Augite-hornblende adamellite*—(34598).—Typical of several low hills just S. of track about 8·5 miles WSW. of Victory Downs Homestead and 3 miles ENE. of Alcurra Creek; flow-banding not obvious, but the attitude of rare xenoliths suggests trend of 335° and possible dip of flow layers 40° NE. In outcrop and thin-section this rock is similar to that at the Alcurra Creek Crossing (30210); plagioclase (47·2%, An 32) extensively replaced by microcline microperthite (20·5%, see Pl. 2, Fig. 6); in addition to normal anhedral grains of sagenitic quartz, some smaller euhedral grains of clear quartz occur with calcite, sphene

TABLE 2

Chemical Analyses, CIPW. Norms, and Modes of Granites from Central Australia.

| | 30558 | 30138 | 30385 | 30397 | 30604 | 30789 | 30210 | 34568 |
|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 66.96 | 66.20 | 65.92 | 65.73 | 64.92 | 63.52 | 63.44 | 61.48 |
| $TiO_2$ | 0.97 | 0.84 | 0.88 | 1.04 | 0.69 | 0.84 | 1.12 | 1.16 |
| $Al_2O_3$ | 14.32 | 14.79 | 14.38 | 14.42 | 15.27 | 16.76 | 15.28 | 16.07 |
| $Fe_2O_3$ | 1.78 | 2.70 | 1.81 | 2.32 | 2.68 | 0.96 | 2.97 | 3.98 |
| FeO | 3.85 | 2.72 | 4.16 | 4.02 | 3.50 | 3.97 | 3.76 | 3.29 |
| MnO | 0.23 | 0.32 | 0.16 | 0.24 | 0.23 | 0.09 | 0.24 | 0.18 |
| MgO | 1.12 | 0.92 | 1.24 | 1.37 | 0.96 | 0.91 | 1.12 | 1.38 |
| CaO | 2.06 | 3.24 | 3.23 | 3.15 | 4.42 | 4.51 | 4.37 | 4.77 |
| BaO | 0.16 | 0.04 | | 0.11 | tr | 0.12 | 0.04 | |
| $Na_2O$ | 2.73 | 3.18 | 3.33 | 2.66 | 2.54 | 3.88 | 3.16 | 2.82 |
| $K_2O$ | 5.14 | 4.30 | 4.16 | 4.34 | 3.71 | 4.01 | 3.58 | 3.59 |
| $H_2O+$ | 0.04 | 0.15 | 0.14 | 0.02 | 0.14 | 0.13 | 0.05 | 0.26 |
| $H_2O$ | 0.18 | nil | 0.16 | 0.06 | 0.04 | 0.06 | 0.05 | 0.24 |
| $P_2O_5$ | 0.33 | 0.56 | 0.38 | 0.46 | 0.76 | 0.52 | 0.55 | 0.85 |
| | 99.87 | 99.96 | 99.95[2] | 99.94 | 99.86 | 100.54[1] | 99.72 | 100.07[3] |

Includes: [3]$S=0.11$, $ZrO_2=0.08$, $Cl=0.07$; [2]$CO_2=nil$; [2]$CO_2=nil$.

CIFW. NORM

| | | 30558 | 30138 | 30385 | 30397 | 30604 | 30789 | 30210 | 34568 |
|---|---|---|---|---|---|---|---|---|---|
| qu | | 24.12 | 23.58 | 20.99 | 24.16 | 25.60 | 14.20 | 20.73 | 20.93 |
| or | | 30.37 | 25.41 | 24.58 | 25.65 | 21.92 | 23.70 | 21.15 | 21.32 |
| ab | | 23.10 | 26.91 | 28.18 | 22.51 | 21.49 | 32.83 | 26.74 | 23.86 |
| an | | 8.36 | 12.49 | 12.01 | 12.82 | 16.97 | 16.48 | 16.94 | 18.10 |
| cor | | 1.20 | 0.33 | | 0.65 | 0.86 | | | 0.91 |
| di | wo | | | 0.64 | | | 1.14 | 0.51 | |
| | en | | | 0.25 | | | 0.36 | 0.24 | |
| | fs | | | 0.40 | | | 0.81 | 0.26 | |
| hy | en | 2.79 | 2.29 | 2.84 | 3.41 | 2.30 | 1.90 | 2.55 | 3.44 |
| | of | 4.42 | 1.97 | 4.59 | 4.19 | 3.50 | 4.21 | 2.77 | 1.17 |
| mt | | 2.58 | 3.92 | 2.63 | 3.36 | 3.89 | 1.39 | 4.31 | 5.77 |
| il | | 1.84 | 1.59 | 1.67 | 1.98 | 1.51 | 1.59 | 2.13 | 2.20 |
| ap | | 0.78 | 1.32 | 0.90 | 1.09 | 1.80 | 1.23 [3] | 1.39 | 2.01 |

[3]Add zir=0.12, pyr=0.20.

MODE (Vol. %)

| | 30558 | 30138 | 30385 | 30397 | 30604 | 30789 | 30210 | 34568 |
|---|---|---|---|---|---|---|---|---|
| Quartz | 26 | 24 | 23 | 28 | 27 | 15 | 21 | 19.7 |
| K-feldspar | 38 | 24 | 27 | 20 | 21 | 24 | 23 | 24 |
| Plagiocl. | 23 | 37 | 37 | 33 | 37 | 49 | 41 | 41 |
| Orthopyrox. | 2 | | 4 | | | 4 | | |
| Clinopyrox. | 3 | | 3 | 2 | 1 | 2 | 3.5 | 1.3 |
| Hornblende | 3 | 1.5 | 1 | 2 | 7 | 0.5 | 4.5 | 5.5 |
| Biotite | tr | 5 | tr | 6 | 0.1 | tr | 0.5 | 0.4 |
| Iron Ores | 4 | 3.5 | 4 | 2 | 5 | 3.5 | 4 | 3.9 |
| Apatite | 0.5 | 1.2 | 1 | 1 | 1.6 | 1.5 | 1.5 | 1.9 |
| Zircon | 0.3 | 0.3 | tr | tr | 0.3 | 0.5 | tr | 0.3 |
| | [4] | [5] | | [6] | | | [7] | [8] |

Add:    [4]calcite=tr; [5]sphene=3, others=0.5; [6]garnet=5; [7]sphene=tr; [8]others=1.

30558. Ferrohypersthene adamellite, Spinifex Hill, Musgrave Ranges. Anal., W. H. Herdsman, 1950.

30138. Hornblende-biotite adamellite (Kulgera Adamellite), Kulgera Hill, Kulgera Hills. Anal., W. H. Herdsman, 1950.

30385. Ferrohypersthene adamellite, Ombaguda, Musgrave Ranges. Anal., W. H. Herdsman, 1951.

30397. Garnetiferous pyroxene adamellite (Upsan Downs Adamellite). The Pass, east of Upsan Downs, Musgrave Ranges. Anal., W. H. Herdsman, 1950.

30604. Hornblende adamellite, near Bald Hill, Musgrave Ranges. Anal., W. H. Herdsman, 1950.

30789. Ferrohypersthene granodiorite, near Ernabella water-hole, Musgrave Ranges. Anal., A. F. Wilson, 1944.

30210. Augite-hornblende adamellite, Alcurra Creek, E. Musgrave Ranges. Anal., W. H. Herdsman, 1950.

34568. Hornblende adamellite (the Ayers Ranges Adamellite), 3¾ miles NW. Mt. Cavenagh homestead, Ayers Ranges. Anal., W. H. Herdsman, 1953.

and biotite as late magmatic crystallizations (total quartz – 16·9%), hornblende (4·1%, γ = 1·682), irregular poikilitic masses corroding clinopyroxene (1·7%, γ – 1·718) and iron ores (4·2%), and closely associated with apatite (1·5%, ω – 1·638); epidote and (?) lawsonite rare accessories associated with chloritized biotite (2·9%, γ = 1·632), calcite, sphene and late iron ores.

## THE AYERS RANGES

The Ayers Ranges (Fig. 1) is a group of hills which rise "like islands out of a vast ocean of scrub" (Giles, 1874, p. 78). Basedow published a sketch map of the general distribution of rocks in the area, and pointed out in his brief report that large portions of the Ranges are apparently composed of somewhat coarsely crystalline normal to slightly porphyritic granite intruded in a direction north of west (Basedow, 1905, p. 78, and Plate XX). He also points out (p. 78) that "outcrops of identical rock were found intermediate in position between Mount Sir Henry and Mt. Carnarvon (Sentinel Hill), thus geologically connecting the Musgrave and Ayers Ranges". Basedow's "intermediate hills" are probably the hills of the Alcurra Creek Region of this paper.

In a brief petrographic description of what he presumably considered to be the typical granite (taken from Mount Sir Henry), Basedow stated (p. 93) that orthoclase was somewhat subordinate to plagioclase, and that the main mafic mineral was a green biotite. In a later, more detailed description of a rock, also presumed to be typical of Mount Sir Henry, Rubinson (1949, p. 38) pointed out that the rock was a hornblende granodiorite. Since Robinson makes no mention of biotite but gives details of a green hornblende it seems likely that Basedow mistook hornblende for biotite.

Reconnaissance mapping with the aid of air-photographs was carried out in the Ayers Ranges in January, 1952. Since papers are being prepared on special aspects of the geology, only the Ayers Ranges Adamellite will be described in this paper. Some of the granitic rocks of the area are coarse porphyritic adamellites, others are granodiorites. The rock described below was chemically analysed, for it appeared to be fairly typical of the acid intrusions of the Ranges. In all of the rocks hornblende appears to be the principal mafic mineral, and clinopyroxene and biotite occur in some. No orthopyroxene was found, and sphene is an accessory in some rocks.

*Hornblende adamellite* (*Ayers Ranges Adamellite*)–(34568).–NW. end of large low bare granite hill 2¾ miles SSW. of Mt. Reynolds and 3½ miles NW. of Mt. Cavenagh Homestead; probably typical of Ayers Ranges; good platy-flowage of K-feldspar phenocrysts trends NW. with dip 60° SW.; nearest known outcrop of gneiss 5½ miles E.

In hand-specimen: coarse-grained purplish grey porphyritic; coarse groundmass of pale pinkish grey K-feldspar and cream-coloured plagioclase; very roughly oriented mafic clots (mostly 10 mm × 5 mm) of black hornblende, iron ore, dull greasy light green augite; few phenocrysts pale pinkish grey K-feldspar (15 mm diam.); occasional light bluish grey plagioclase (15 mm × 12 mm).

In thin-section (supplementing Table 1): occasional phenocrysts of K-feldspar set in coarse xenomorphic granular groundmass; andesine, non-zoned, mostly 2 mm diam., albite-pericline twins curved, shattered and healed by K-feldspar and sometimes by apatite or hornblende, many inclusions of distorted magnetite octahedra and rutile needles, corrosion by K-feldspar not as common as in many comparable granitic rocks of Central Australia, but myrmekite present, K-feldspar, moderately microperthitic, no cross-hatch twinning; non-sagenitic quartz; hornblende corrodes iron ores and clinopyroxene, and smears of magnetite dust in hornblende suggest early replacement of ferriferous

pyroxene, pleochroism — yellowish fawn, greenish khaki, green; biotite, mostly corroding iron ores and hornblende in mafic clots, pleochroism — very pale yellow, golden brown; zircon, colourless, mostly euhedral crystals associated with mafic clots, fluorescent as in other rocks of this suite; epidote, lawsonite, greenish biotite are rare secondary minerals.

Details of mineral compositions are set out in Table 1.

A *chemical analysis, norm* and *mode* of this rock are set out in Table 2, *ion percentages* are set out in Table 6, and further reference is made in Figs. 5 and 6. A discussion of these data is reserved for the petrogenesis section.

### THE KULGERA HILLS

The Kulgera Hills are separated from the Ayers Ranges, which are some ten miles to the south, by a trough in which remnants of flat-lying (?) Mesozoic sandstones are the only outcrops (Fig. 1). Gneisses, mostly of amphibolite facies, trend approximately 330° to 340° (both strike and lineation). In places these are heavily granitized, and some are cut by magmatically-emplaced granites, microgranites and muscovite-bearing pegmatites. Notwithstanding marked local transgressive structures, the overall trend of the granite intrusions appears to be sub-parallel to the fold axes of the gneisses, i.e., 330° to 340° (Fig. 1).

The first geological study of this area was made by the author in 1949 when the main distribution of rock types and structure were worked out. Some features of the granitic rocks of the Kulgera Hills have been published (Wilson, 1950b, pp. 228, 230; 1952a, p. 78), and other papers await publication.

In the present paper a description is given of the Kulgera Adamellite, the most important granitic rock of the region.

*Hornblende-biotite adamellite* (The Kulgera Adamellite) — (30138).—East face of Kulgera Hill, one mile ENE. of Kulgera Homestead; coarse massive even-grained rock composed of flesh-coloured microcline, dull white plagioclase (with occasional phenocrysts of bluish grey plagioclase, 30 mm long), shiny black biotite, dull black hornblende and plentiful accessory brown sphene; microcline fluoresces pink and zircon yellow (Wilson, 1950b, pp. 227-228, 230).

In thin-section (supplementing Table 1): coarse xenomorphic texture with non-oriented mafic clots; oligoclase, An 26, slightly zoned to An 23 near the edges of large crystals, grotesquely-shaped relics within well-twinned microcline microperthite, or as aggregates of subhedral tabular crystals which, by their bent and fractured twin-lamellae, indicate some (?) protoclastic shearing prior to or during their partial replacement by microcline, rods of rutile and flakes of haematite common inclusions; sagenitic quartz; biotite, corroding hornblende and iron ores, tends to occur as buffer between these minerals and microcline, pleochroism — pale fawn, dark brown; iron ores (3-5%) — mostly magnetite, prominent constituent of mafic clots, in places corroded by sphene, hornblende or biotite; pale fawn sphene, and a little purple fluorite, are in contact with microcline and corrode iron ores; hornblende, corrodes iron ores and is itself corroded by biotite, pleochroism — pale greenish fawn, khaki-green, clear greenish blue.

Details of mineral compositions in Table 1.

A *chemical analysis, norm* and *mode* of this rock are set out in Table 2, *ion percentages* are set out in Table 6, and further reference is made in Figs. 5 and 6. Discussion of these data is reserved for the petrogenesis section

## MINERALOGY

Notwithstanding the marked differences in appearance in hand-specimen, the main granitic intrusions of a large portion of the Musgrave Block show many

mineralogical and textural features in common. The general range of properties of the minerals is set out below.

## QUARTZ

Bluish-grey in hand-specimen (as in many Indian charnockitic rocks) in only some orthopyroxene-bearing granites; bluish tint absent from clinopyroxene-bearing, and hornblende-bearing granites; quartz not always sagenitic; sagenitic quartz not restricted to pyroxenic granites; may also occur as small rounded grains (sagenitic or otherwise) in K-feldspar (Pl. 2, Fig. 4); water-clear blebs may be included in hornblende.

## K-FELDSPAR

Mostly moderately micro-perthitic non-twinned microcline, presumably inverted from monoclinic phase (Wilson, 1950a, p. 219); typical cross-hatch twinning of microcline best seen in biotite-rich or sphene-bearing granitic rocks where it may show characteristic pale pink fluorescence (Wilson, 1950b, p. 232); pronounced corrosive action on plagioclase (discussed, p. 49); no phenocrysts of K-feldspar in the orthopyroxenic granites described in this paper, but are important in some granites from the Ayers Ranges.

## PLAGIOCLASE

Similar *habit* in both orthopyroxene-bearing and orthopyroxene-free granites; mostly as corroded relics 2 mm diam. from probable originals at least 6 mm long; rare bluish-grey non-zoned phenocrysts up to 40 mm × 12 mm in some pyroxenic granites, but greasy blue phenocrysts about 20 mm × 8 mm not rare in many hornblende-bearing granites of Ayers Ranges and eastern outliers of Musgrave Ranges. *Composition* of phenocrysts or groundmass very similar in either orthopyroxenic rocks or otherwise (see Table 1.); determined (by reference to Winchell and Winchell (1951, p. 283)) from extinction $a' \wedge 010$ in sections $\perp a$ (to conserve space, recorded thus: "extinction = 20°"); in orthopyroxenic granites commonly andesine (about An 37) (contrast (a) "charnockitic adamellite" from Kakamas, South Africa (Poldervaart and von Backström, 1949)): phenocrysts commonly strongly zoned (An 54-28 with average composition An 45); plagioclase non-zoned in Australian rocks. (b) Finnish "charnockites" at Turku (Hietanen, 1947, p. 1039) with trondhjemitic affinities: comparable rocks much more sodic (An 25 — An 33) than the Australian rocks). Dark colour of plagioclase in hand-specimen probably due to almost ubiquitous presence of *inclusions* (? exsolution phenomena) such as slender, hair-like crystals of rutile (as in quartz of many associated rocks), and associated in some grains with erratic development of squat rods of rutile, octahedra of magnetite or flakes of haematite. Albite and pericline *twin-lamellae* of almost all rocks bent and fractured; development of the twinning appears to have been facilitated and even controlled by shearing in many rocks: K-feldspar replacement possibly proceeded *pari passu* with shearing (see p. 68), and there is probably a similar control for erratic and poor development of micro-antiperthite which is here of replacement not exsolution origin (see p. 68).

## ORTHOPYROXENE

Within restricted areas hypersthene-bearing and hypersthene-free granites closely associated as though of similar age and genetically related (e.g., Sentinel Hill); orthopyroxenic granites restricted (as far as is known) to Musgrave Ranges; in some rocks evidence of development at expense of clinopyroxene; in others a lamellar structure (// optic plane (010)) in orthopyroxene is some-

what bent and shattered, and the mineral corroded by unsheared clinopyroxene; in many rocks, no clear evidence of order of crystallization of the two pyroxenes. *Composition* estimated by measurement of $\gamma$ in immersion liquids in sodium light (accuracy about $\pm 0 \cdot 001$, and reference to the graph by Hess (1952, Fig. 2)); outstanding feature is very ferriferous character (range Fe 65½ to Fe 50 with average about Fe 57) in marked contrast with less ferriferous basement granulites (average about Fe 37 and maximum Fe 50, and marked tendency for most ferriferous orthopyroxenes to occur in granulites of intermediate rather than basic or acid composition); chemical and modal analyses of the Central Australian granites show that more ferriferous pyroxenes (both ortho- and clino-) are in the more basic of the granitic rocks; contrast the commonly recorded iron-enrichment in acid differentiates of igneous bodies and note that Hietanen (1947, p. 1040) points out that the iron content of the pyroxenes (both ortho-and clino-) seems to rise regularly with increasing silica-content in the charnockite series of Turku, Finland, where charnockitic rocks are basic, intermediate and acid types, and said to be magmatic and related to trondhjemites; very ferriferous orthopyroxenes also typical of intermediate charnockites from Varberg, Sweden (Quensel, 1951, p. 247), where orthopyroxenes from two typical rocks, more basic than the rocks described in the present paper, contain Fe 64½ and Fe 77½ respectively (using Hess's graph (1952, Fig. 2)). Dispersion, r < v, for observed range of composition (cf., Kuno, 1941). Correlation between composition as suggested by $\gamma$ and 2V not as good as for orthopyroxenes of basement granulites. Pleochroism weak as in most other ferriferous orthopyroxenes of other charnockitic areas (e.g., Quensel, 1951, p. 248; Hietanen, 1947, p. 1038; Howie, 1955, p. 753) – colours noted, $\alpha$ = pale pinkish fawn, $\beta$ = pale fawn, $\gamma$ = very pale greenish grey.

### CLINOPYROXENE

Present in all rocks under discussion except certain granites very rich in hornblende and biotite, and some sphene-bearing rocks; in orthopyroxenic granites confusing evidence of pyroxene relations (as pointed out above); in many hornblende-rich rocks clinopyroxenes strongly corroded by hornblende; in addition to normal (110) cleavage, (100) and (001) partings usually strongly developed, and (010) partings less prominent; very fine lamellar structure commonly developed // (100); exsolution lamellae of orthopyroxene not common; inclusions of corroded orthopyroxene and magnetite uncommon; cleavages and lamellar structures not curved as commonly as those of orthopyroxene of same rock; colour—clear, very pale greenish grey with very rare weak pleochroism. *Composition*—estimated by using $\gamma$ (measured in Na light on grains yielding centred flash figure—owing to poor (010) parting such grains not difficult to locate) and 2V, and appropriate curves (superimposing plates I and II: Hess, 1949); accuracy about $\pm 2\%$ for each component, since influence on optics of Al, $Fe^3$, Ti, etc., not known; extinction $\gamma \wedge c$, measured directly in Na light on universal stage by orienting grains normal to both (001) and (100) partings, and accurate to $\pm 1°$; mostly calcic augites, somewhat more ferriferous than those of basement granulites (Fig. 3). The optically derived compositional tie-lines of *co-existing pyroxenes* in intrusive orthopyroxenic granites are distinctly different from those of basement granulites, thus suggesting a possible method for recognizing intrusive (mobilized) charnockitic rocks, for Hess (1941, p. 585) pointed out that for igneous rocks "if a line joining the two pyroxenes of a given specimen be extended upwards to the En-Wo composition line it will intersect that line at approximately En 25 Wo 75"—contrast C. Australian orthopyroxenic granites (En 24½ Wo 75½), and basement granulites (En 15½ Wo 84½). The

compositional tie-lines are shown in Fig. 3. The significance of variation in optically derived tie-line trends of co-existing pyroxenes has been discussed elsewhere (Wilson, 1959b).
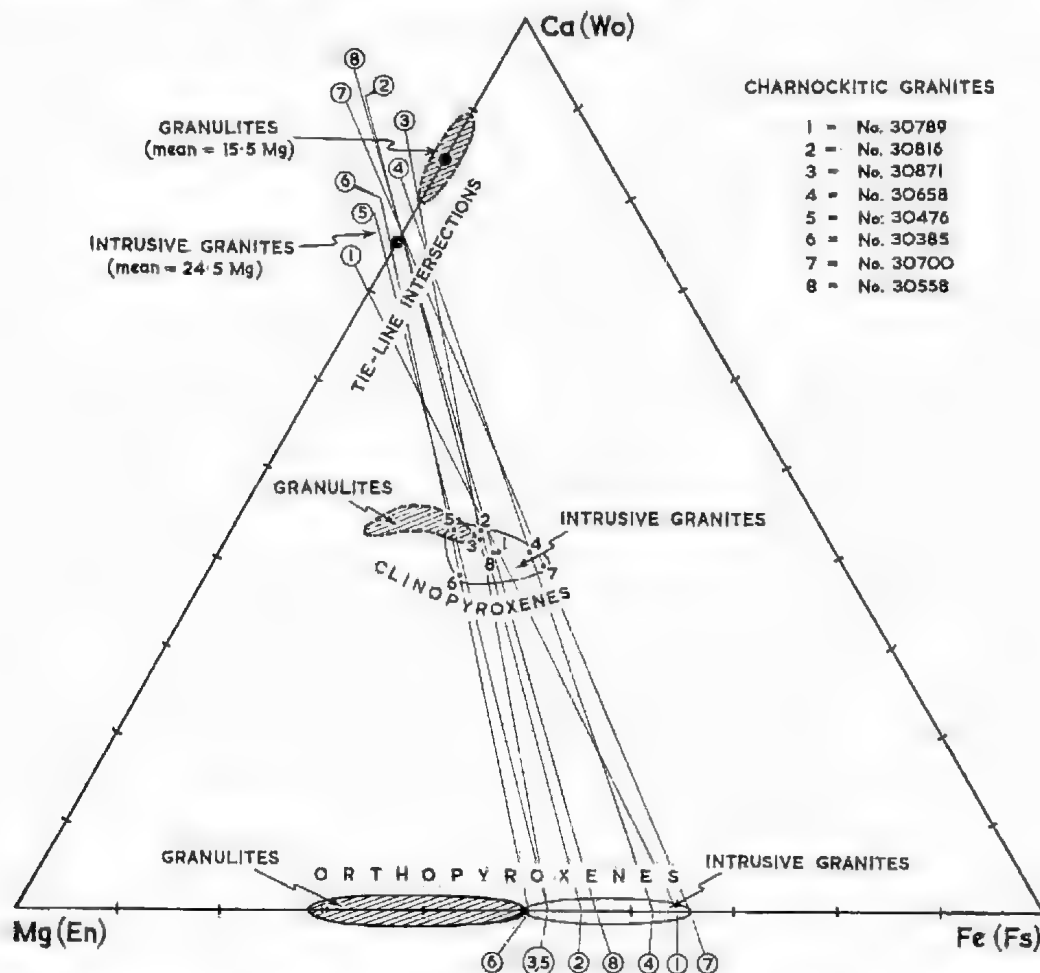


Fig. 3.—The optically derived compositional tie-lines of co-existing pyroxenes in charnockitic granites compared with those of the granulites which are intruded by the granites.

## AMPHIBOLE

*Hornblende of the orthopyroxenic granites*: Dominant mafic mineral in some, absent from others; normally charged with apatite and corrodes iron ores (Pl. 2, Fig. 4) and both pyroxenes; in some rocks grotesque poikilitic masses developed largely at expense of plagioclase and associated with granules of clear quartz in contrast to more normal sagenitic quartz of rest of rock; $\gamma$ ranges from $1\cdot703$ to $1\cdot685$ with higher values in more basic rocks; pleochroism—$a$ = pale fawn or fawn, $\beta$ = brown or dark khaki, $\gamma$ = greenish khaki, with $\beta > \gamma > a$; $2V/a = 72°$ to $78°$; $\gamma \wedge c = 15°$ to $19°$; probably ferriferous hastingsites; consistently more ferriferous than hornblendes of basement pyroxenic granulites.

*Hornblende of the clinopyroxenic and hornblendic granites*: Habit and mineral associations, $2V$ and $\gamma \wedge c$ are similar to those of hornblende of ortho-

pyroxenic granites, but refractive indices ($\gamma$ range $1 \cdot 682$-$1 \cdot 673$) consistently lower (only exceptions: sphene-bearing biotite adamellite from Kulgera, 30138, in which $\gamma = 1 \cdot 692$; pleochroism – $\alpha$ = pale greenish fawn, $\beta$ = khaki green, $\gamma$ = clear greenish blue, and a similar rock from Stony-Jump-Up, Musgrave Ranges). Pleochroism (for $\gamma = 1 \cdot 681$ to $1 \cdot 682$, $\gamma \wedge c = 18°$) – $\alpha$ = pale fawn, $\beta$ = khaki green, $\gamma$ – yellowish green, or (for $\gamma = 1 \cdot 673$, $\gamma \wedge c = 17°$) $\alpha$ = yellowish fawn, $\beta$ = greenish khaki, $\gamma$ = green. In composition, hornblendes of granites free from orthopyroxene are less ferriferous than those of orthopyroxenic granites.

### BIOTITE

*Biotite of the orthopyroxenic granites*: Rare, but may occur as small irregular grains encrusting some grains of iron ore and hornblende; strongly pleochroic – $\alpha$ = light straw-yellow; $\beta = \gamma$ = chestnut brown; $\gamma$ ranges from $1 \cdot 640$ to $1 \cdot 665$ indicating biotite more ferriferous than in granites devoid of orthopyroxene; $2V/\alpha$ mostly $0°$.

*Biotite of granites devoid of orthopyroxene*: Plentiful; corrodes iron ores and hornblende, and in some rocks (e.g., 30138) biotite tends to act as buffer between those minerals and corroding microcline; pleochroic haloes rare (best seen in 30573); mostly biaxial ($2V/\alpha = 0°$ to $15°$, r < v, strong); $\gamma$ ($1 \cdot 632$ to $1 \cdot 616$) lower than for biotites of orthopyroxenic granites; pleochroism – $\alpha$ = fawn, $\beta$ = chestnut brown, $\gamma$ = yellowish brown, or $\alpha$ = very pale yellow, $\beta = \gamma$ = golden brown.

*Biotite of pegmatites*: In pegmatites closely associated with orthopyroxenic granites near Ernabella, greenish khaki or khaki in thin (001) flakes, sensibly uniaxial negative with $\gamma$ ranging $1 \cdot 654$ to $1 \cdot 678$ (one biotite has $2V/\alpha = -7°$, $\gamma = 1 \cdot 680$); more ferriferous than those of orthopyroxenic "parent rocks".

### IRON ORES

Ilmenite and magnetite of equal importance as main iron ores, and pyrite and pyrrhotite very rare; corroded grains in pyroxene, hornblende and biotite in the basic clots, small octahedral inclusions of magnetite in plagioclase, irregular plates "healing" shears and gashes in most minerals (Pl. 2, Figs. 3 and 4), small euhedral orange-coloured and red flake inclusions of (?) haematite in some plagioclase grains.

### FLUORAPATITE

Abundant accessory; no consistent differences in composition or type of inclusion (commonly colourless tubular inclusions alined // $c$) or fluorescence (in some rocks pale dull yellow in contrast with associated zircons which always fluoresce bright yellow or orange) notwithstanding variable habit as subhedral masses intimately associated with all minerals of mafic clots, or as euhedral grains in hornblende, or as euhedral grains in K-feldspar near contact with plagioclase grain in process of replacement by K-feldspar (as though P and F fixed by Ca expelled from plagioclase by K)—see Pl. 2, Figs. 2 and 6.

### ZIRCON

Clear, almost colourless, non-zoned, euhedral grains usually associated with mafic clots; commonly with characteristic tubular and crystal inclusions; bright yellow or orange fluorescence (2537 Å); only one type in intrusive rocks (contrast with several types in some basement granulites), thus suggesting close genetic relationship as discussed in previous papers (Wilson, 1947b, pp. 201, 209; 1950b, p. 209); similar zircons occur in granulites which have suffered extreme metasomatic activity and recrystallization (compare Poldervaart and von Backström, 1949, p. 467: "recrystallization of zircon accompanies the produc-

Acid and Intermediate Charnockitic Rocks, including some known to be magmatically emplaced.

| | 1 | 2 | 3 | 4* | 5 | 6* | 7 | 8 | 9 | 10* | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 77.47 | 70.63 | 69.57 | 66.96 | 66.93 | 65.92 | 65.89 | 64.62 | 63.85 | 63.52 | 60.45 | 60.12 |
| $TiO_2$ | 0.26 | 0.61 | 0.02 | 0.97 | 2.59 | 0.88 | 0.55 | 1.26 | 0.83 | 0.84 | 1.50 | 0.95 |
| $Al_2O_3$ | 11.00 | 14.34 | 15.08 | 14.32 | 12.50 | 14.38 | 14.89 | 13.76 | 14.87 | 16.76 | 17.56 | 16.63 |
| $Fe_2O_3$ | 1.04 | 0.32 | 0.26 | 1.78 | 0.87 | 1.81 | 2.00 | 3.28 | 2.32 | 0.96 | 0.62 | 2.19 |
| $FeO$ | 2.02 | 2.20 | 3.29 | 3.85 | 4.25 | 4.16 | 3.10 | 3.52 | 5.07 | 3.97 | 5.77 | 4.79 |
| $MnO$ | nil | 0.04 | 0.02 | 0.23 | | 0.16 | 0.04 | 0.11 | 0.05 | 0.09 | 0.10 | 0.10 |
| $MgO$ | 0.43 | 0.56 | 2.09 | 1.12 | 1.36 | 1.24 | 2.10 | 1.62 | 3.29 | 0.91 | 1.60 | 0.82 |
| $CaO$ | 1.02 | 2.04 | 2.62 | 2.06 | 3.43 | 3.23 | 5.25 | 5.06 | 4.48 | 4.51 | 4 72 | 3.75 |
| $BaO$ | | | 0.20 | 0.16 | 0.18 | | | | nil | 0.12 | 0.18 | 0.21 |
| $Na_2O$ | 2.86 | 3.02 | 2.87 | 2.73 | 2.82 | 3.33 | 2.42 | 2.59 | 3.72 | 3.88 | 3.75 | 4.73 |
| $K_2O$ | 4.14 | 5.59 | 3.99 | 5.14 | 3.39 | 4.16 | 3.18 | 3.58 | 1.09 | 4.01 | 2.45 | 4.25 |
| $H_2O+$ | 0.20 | 0.40 | }0.53 | 0.04 | 0.38 | 0 14 | | 0 33 | }0.11 | 0.13 | 0 75 | 0.25 |
| $H_2O-$ | 0.05 | 0.09 | | 0.18 | 0.08 | 0.16 | | 0.10 | | 0.06 | 0.53 | |
| $P_2O_5$ | nil | 0.25 | 0.04 | 0.33 | 0.78 | 0.38 | 0.29 | 0.65 | 0.08 | 0.52 | 0.31 | 0 77 |
| $S$ | | | 0 08 | | | | 0.12 | | 0.15 | 0.11 | 0 09 | |
| $ZrO_2$ | | | tr | | | | | | tr | 0.08 | 0 01 | |
| | 100.49 | 100.09 | 100.66[1] | 99.87 | 99.89[2] | 99.95[3] | 99.83 | 100.48 | 99.95[4] | 100.54[5] | 100.39[6] | 99.56 |

Includes:— [1]SrO =tr; [2]SO$_3$=0.26; [3]CO$_2$=nil; [4]SrO=0.04, Cl=nil; [5]Cl -0.07, CO$_2$=nil; [6]CO$_2$=nil.

CIPW. NORM

| | 1 | 2 | 3 | 4* | 5 | 6* | 7 | 8 | 9 | 10* | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| qu | 41.22 | 24.3 | 25.26 | 24.12 | 29.46 | 20.99 | 25.56 | 24.9 | 20.95 | 14.20 | 13.88 | 7.26 |
| or | 24.46 | 33.3 | 23.91 | 30.37 | 20.02 | 24.58 | 18 90 | 21.1 | 6.67 | 23.70 | 15.01 | 25.02 |
| ab | 24.10 | 27.7 | 24.63 | 23.10 | 23.58 | 28.18 | 20.44 | 22.0 | 31.44 | 32.83 | 31.44 | 39.82 |
| an | 5.00 | 8.8 | 13.07 | 8 36 | 11.68 | 12.01 | 20 29 | 15.3 | 20 57 | 16.48 | 21.78 | 11.68 |
| cor | | | 1.12 | 1.20 | | | | | | | 0.64 | |
| di {wo | | | | | | 0 64 | }3.40 | 2.1 | }1.36 | 1.14 | | }1.89 |
| {en | | | | | | 0 25 | | 1 4 | | 0.36 | | |
| {fs | | | | | | 0.40 | | 0 5 | | 0 81 | | |
| hy {en | }3.34 | 1.6 | }10.81 | 2.79 | }5.84 | 2.84 | }6.31 | 2.7 | }13.74 | 1.90 | }11.66 | 6.68 |
| {of | | 2.4 | | 4.42 | | 4.59 | | 1,2 | | 4.24 | | |
| mt. | 1.62 | 0.4 | 0 46 | 2.58 | 1.39 | 2.63 | 3.02 | 4.9 | 3.25 | 1.39 | 0.93 | 3.25 |
| il | 0.61 | 1.0 | | 1.84 | 5.02 | 1.67 | 1.06 | 2 4 | 1.52 | 1.59 | 2.89 | 1.82 |
| pyr | | | | | | | 0.22 | | | .20 | | |
| ap | | 0 5 | | 0.78 | 2 02 | 0 90 | 0.67 | 1.7 | | 1.23 | 0 67 | 1.68 |
| zir | | | | | | | | | | 0 12 | | |

MODE (Vol. %)

| | 1 | 2 | 3 | 4* | 5 | 6* | 7 | 8 | 9 | 10* | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Quartz | 40 | 26 8 | 20.3 | 26 | 29.46 | 23 | | 27.1 | 15 5 | 15 | 11 0 | |
| K-feldspar | }54 | 42.3 | }58.0 | 38 | 20.02 | 27 | | 22.7 | }55.5 | 24 | }49 | |
| Plagiocl. | | 23.4 | | 23 | 33.58 | 37 | | 29 8 | | 49 | | |
| Orthopyrox. | 3 | 5.7 | 12 3 | 2 | }7.52 | 4 | | }3.8 | 23.6 | 4 | 12.0 | |
| Clinopyrox. | | | | 3 | | 3 | | | | 2 | 1.6 | |
| Hornblende | | | | 3 | | 1 | | 2.5 | | 0 5 | 14.3 | |
| Biotite | 1 | 0 3 | 9 4 | tr | | tr | | 5.7 | | tr | | |
| Iron ores | 2 | 1.2 | | 4 | 6.41 | 4 | | 6.6 | 5.4 | 3.5 | 6.9 | |
| Apatite | | 0.3 | | 0.5 | 2.02 | 1 | | 1.3 | | 1.5 | | |
| Zircon | | | | 0.3 | | tr | | | | 0.5 | | |
| Etc. | | | | | | | | 0.5[7] | | | 5.1[8] | |

[7]mostly sphene; [8]garnet.

| | 1 | 2 | 3 | 4* | 5 | 6* | 7 | 8 | 9 | 10* | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S.G. | 2.67 | | 2.77 | 2.705 | 2.80 | 2.728 | 2.74 | 2.78 | 2.77 | 2.737 | 2.72 | 2.77 |

1. Charnockite, St. Thomas' Mount, Madras, India (Washington, 1916, p. 325).
2. Charnockite, Ivy Point, Alfred County, Natal, S. Africa (Gevers and Dunne, 1943, p. 201).
3. Charnockite, Bunyore district, Uganda (Groves, 1935, p. 163).
4. *30558. Ferrohypersthene adamellite, Spinifex Hill, Musgrave Rgs., C. Australia. Anal., W. H. Herdsman, 1950.
5. Charnockite, Nuwara Eliya, Ceylon (Adams, 1929, p. 481).
6. *30385. Ferrohypersthene adamellite, Ombagunda, Musgrave Rgs., C. Australia. Anal., W. H. Herdsman, 1951.
7. Charnockite, Galle, Ceylon (Adams, 1929, p. 481).
8. Charnockite adamellite, Kakamas, Cape Province, S. Africa (Poldervaart and von Backström, 1949, p. 487).
9. Intermediate charnockite, Yercaud, Shevaroy Hills, Madras State, India (Washington 1916, p. 328).
10. *30789. Ferrohypersthene granodiorite, Ernabella, Musgrave Rgs., C. Australia. Anal., A. F. Wilson, 1944.
11. Quartz-hypersthene diorite, Mt. Wati, Uganda (Groves, 1935, p. 166).
12. Intermediate charnockite, Fästningsberget, Varberg, Sweden (Quensel, 1951, p. 258).

*Indicates a new analysis.

tion of ultrametamorphic granite"); in pegmatites closely associated with both the orthopyroxene-bearing granites in Ernabella region and sphene-bearing hornblende-biotite granites of the Kulgera Hills, very dark brown weakly radioactive non-fluorescent zircon (possibly cyrtolite) occurs as euhedral crystals up to 2 cm. long (Wilson, 1947b, p. 208).

### SPHENE

Absent from orthopyroxene-bearing granites, but very rare accessory in pegmatites closely associated with these rocks near Ernabella; usually absent from clinopyroxene-bearing granites, but appears as crusts on some ilmenite in a few of the granites from Ayers Ranges; abundant in some biotite-rich granites (especially those containing a hornblende more typical of rocks of the amphibolite rather than granulite facies, e.g., 30138 and 30573); some petrographic evidence of its formation by fixation of Ti from ilmenite by Ca liberated from plagioclase in process of corrosion by K-feldspar; sphene and bluish-green amphibole are late magmatic phenomena in charnockitic adamellites of Kakamas, South Africa (Poldervaart and von Backström, 1949, p. 486), and sphene is rare in Swedish charnockitic rocks (Quensel, 1951, p. 251).

### CALCITE

Rare, apparently late magmatic concentration in both orthopyroxenic and biotite-rich granites.

### GARNET

Garnet absent, but spessartitic types (with $n = 1·817$, approx.) in associated pegmatites; basement rocks commonly garnetiferous (see p. 66).

### RUTILE

As needles in some quartz and plagioclase.

### ALLANITE

Absent from granites, but found in pegmatites closely associated with the granites of the whole area.

## PETROGENESIS

### CHEMICAL DATA

Eight new chemical analyses of granites from the Musgrave Block are set out, together with CIPW. norm, and mode in Table 2. Three are of orthopyroxenic granites ("charnockites") (30588, 30385 and 30789), and also appear in Table 3 with other orthopyroxenic rocks.

### NOTES ON INDIVIDUAL ANALYSES

*Ferrohypersthene adamellite*, 30558 (Table 3, 4; Table 2).—Petrography, p. 48; in hand-specimen closely resembles type acid charnockite from Madras (Table 3, 1), but this resemblance is of no chemical significance for the greasy dark grey colour is a feature of a wide range of pyroxenic rocks; similar to acidic charnockite from Uganda (Table 3, 3), and Ba content of both rocks is high, a feature noted by Groves (1935, p. 174) in several charnockitic rocks from Uganda; similar to some charnockitic rocks from Ceylon (Table 3, 5 and 7), but is more potassic (late magmatic enrichment in K reflected in analysis—see Fig. 6).

*Hornblende-biotite adamellite* (the Kulgera Adamellite), 30138 (Table 2).— Petrography, p. 54; sphene-bearing granite devoid of pyroxene, and emplaced within rocks of amphibolite facies; chemically similar to more deep-seated rocks

west of Kulgera (all other analyses of Table 2, and see discussion, p. 64), but ratio of ferrous to ferric iron much lower in 30138, and Ba low.

*Ferrohypersthene adamellite*, 30385 (Table 3, 6; Table 2).—Petrography, p. 46; very similar to 30558, thus resembling some charnockitic rocks from Ceylon (Table 3, 5 and 7) and from South Africa (Table 3, 8); richer in Ca than 30558, as shown by appearance of diopside in the norm in 30385, but both rocks contain modal clinopyroxene; high ratio of ferrous to ferric iron in both modal and normative pyroxenes is significant (see p. 64).

*Garnetiferous pyroxene adamellite* (The Upsan Downs Adamellite), 30397 (Table 2).—Formal description not in this paper; typical of granites of Upsan Downs region, all of which have suffered a characteristic metamorphism with production of abundant microscopic pink garnet ($n = 1 \cdot 799$) developed at expense of iron ores and pyroxenes during (?) deep-seated shearing; many granites converted to flaser-granites and augen-gneisses; approximate mode of 30397, the typical granite from the middle of The Pass (about 1 mile E. of Upsan Downs Well) set out in Table 2; no orthopyroxene remains but was probably present in the igneous rock prior to the metamorphism; chemical analysis remarkably similar to those of other granites from the Musgrave Ranges.

*Hornblende adamellite*, 30604 (Table 2).—Petrography, p. 49; this ortho-pyroxene-free rock probably typical of the hornblende facies of the Ernabella Adamellite; main chemical difference — Ernabella rock (30789) contains much less $Fe_2O_3$ and $P_2O_5$ but more $Na_2O$; very similar to 30210, the augite-hornblende adamellite from Alcurra Creek, and to 30138, the sphene-bearing hornblende-biotite adamellite from Kulgera, moreover, all three rocks unusually low in BaO.

*Ferrohypersthene granodiorite* (close to adamellite), 30789 (Table 3, 10; Table 2).—Petrography, p. 44; when first analysed, thought typical of granites in vicinity of Ernabella where orthopyroxenic granites best displayed in Musgrave Ranges; normative and modal quartz are lower than in any other granite from the area, and owing to the high potash-content it is not a typical grano-diorite; further work now shows that this rock, 30789, may be considered a slightly more basic facies of the Ernabella Adamellite; although closely re-sembling 30385 and 30558 (the other two analysed orthopyroxenic granites from Musgrave Ranges) 30789 is not closely comparable with other charnoc-kitic rocks; some resemblance to "quartz-hypersthene diorite" from Uganda (Table 3, 11), but closer to intermediate charnockite from Sweden (Table 3, 12), thus pointing out another feature of this rock, viz., it could be of intermediate composition rather than acid if it were not for its high potash content and high modal quartz — petrographic evidence for late magmatic replacement of plagio-clase by K-feldspar is significant especially since similar replacements are more common in 30558, a rock otherwise similar to 30789; the high $FeO/Fe_2O_3$ ratio is feature of orthopyroxenic granites of Musgrave Ranges, and of charnockitic rocks of Uganda and Sweden.

*Augite-hornblende adamellite*, 30210 (Table 2).—Petrography, p. 51; typical of Alcurra Creek region, and similar to 34568 from Ayers Ranges and 30604 from Musgrave Ranges; link with 30604 and 30138 suggested by low BaO content of all three rocks.

*Hornblende adamellite* (the Ayers Ranges Adamellite), 34568 (Table 2).—Petrography, p. 53; typical of Ayers Ranges; although the least silicic of the analysed granites, contains over 20 per cent. normative quartz; low ratio $FeO/Fe_2O_3$ as in most non-orthopyroxenic granites; $TiO_2$ and $P_2O_5$ more abun-dant than in any other analysed granite from the Musgrave Block.

GRAPHICAL METHODS FOR THE STUDY OF THE ANALYSES

Both Harker and Larsen linear diagrams were prepared but show no significant features not equally well shown by other diagrams.

*Larsen triangular diagrams.*—These diagrams show the relative proportions of Or, Ab and An (shown by •), and Felsic, Quartz and Femic constituents (shown by o) as calculated from the CIPW. norm. A study of the length and slope of the lines joining the two points of a group of analyses has commonly lead to indications of differentiation trends, and has suggested which rocks of a group are magmatically related (Larsen, 1938). In the calculations for the diagrams in the present paper the small amount of corundum has been ignored.
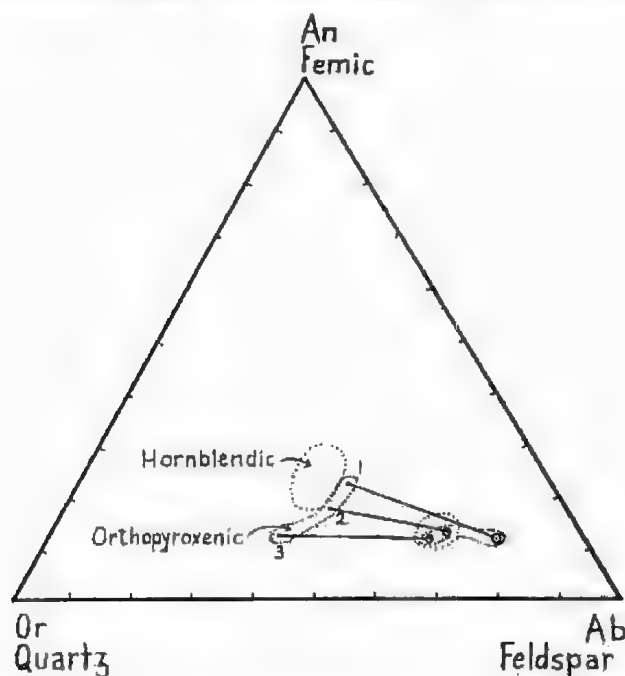


Fig. 4.—Variation in proportions of normative minerals of three related *orthopyroxene-bearing granites*. Limits of variation of *associated hornblende-bearing granites* are also shown. 1 = 30789, 2 = 30385, 3 = 30558.

In Fig. 4 the Or-Ab-An field and the Quartz-Felsic-Femic field of the three orthopyroxene-bearing granites are compared with those of the five other granites of Table 2. The fields for the non-orthopyroxenic granites (taken from Fig. 5) show remarkable similarity. The shape of the fields for the orthopyroxene-bearing granites, however, is interesting. The shape of the Or-Ab-An field tends to support the conclusion suggested by the petrography that, prior to considerable late-magmatic replacement of plagioclase by K-feldspar and quartz, 30558 was similar to 30789.

*Brammall triangular diagrams.*—These diagrams show the relative proportions of Or + Cor, Ab, and An + Femic as calculated from the CIPW. norm. Brammall used such variation diagrams in an attempt to show the importance of syntexis and differentiation in igneous rocks. The positions of average shale, sandstone, phyllite, mica schist and limestone are after Brammall (1933, p. 101, Fig. 1). The position of average greywacke was calculated from Pettijohn's average greywacke (1949, p. 250, Table 64, analysis G).

Fig. 6 shows the position of the analysed granites described in this paper. The three orthopyroxenic granites (A, B and C) are clearly related. The diagram illustrates the petrographic evidence that the granite from Spinifex
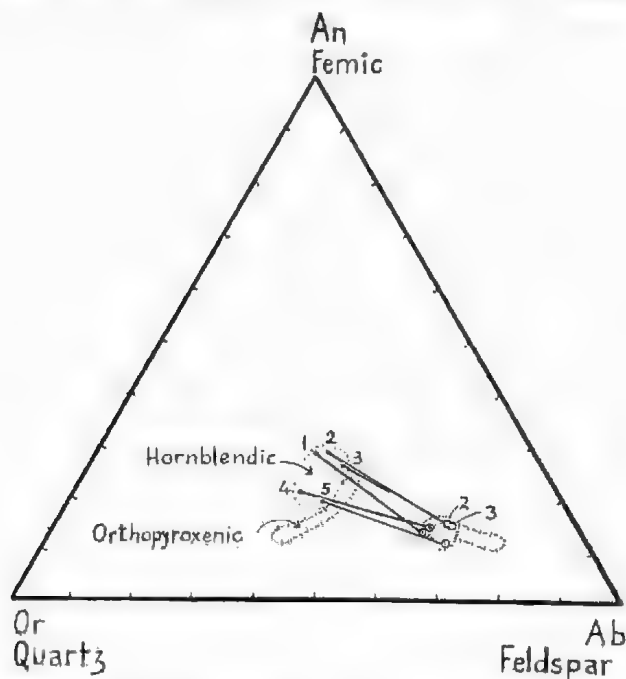


Fig. 5.—Variation in proportions of normative minerals of *hornblende-bearing granites*. Limits of variation of related orthopyroxene-bearing granites are also shown.
1 = 30604, 2 = 34568, 3 = 30210, 4 = 30397, 5 = 30138.

Hill (C) has been formed from a rock like A (from Ernabella) by late magmatic replacement of plagioclase by K-feldspar.

The non-orthopyroxenic granites are also shown in Fig. 6. The granites from the Ayers Ranges (F), Alcurra Creek (E), and Bald Hill (D) are all remarkably alike chemically, even in lesser components, such as BaO and MnO. These three rocks appear very close together in Fig. 6, tending to confirm the petrographic evidence of the co-magmatic relationship between the granites of the three areas. The sphene-bearing granite from Kulgera (G) appears from the diagram and petrography to be a slightly alkaline differentiate of the granite from the Ayers Ranges (F).

The bulk of the granites are found to lie between average greywacke (S) and average mica schist (T). This could be taken as evidence in favour of a palingenetic origin of the granites.

Four analysed granitic granulites from the basement complex are also shown in Fig. 6, and certain basic granulites are shown on the lower continuation of the trend-line through the acid granulites. The similarity of the trend-lines of the metamorphic and igneous rocks is obvious. Its significance, however, is probably not as great as one might be tempted to think. Rocks which, for various reasons, have been largely converted to granite-like rocks during regional metamorphism may be expected to fall on a "trend-line" comparable with that displayed by these granulites. The curve merely means that as basic rocks become less femic the tendency is for them to become first enriched in soda feld-

spar and later in potash feldspar. The differentiation curve is that shown by "normal" igneous rocks (whether ultimately derived from melts or by palingenesis). It would seem that while "Brammall diagrams" are useful as pictorial
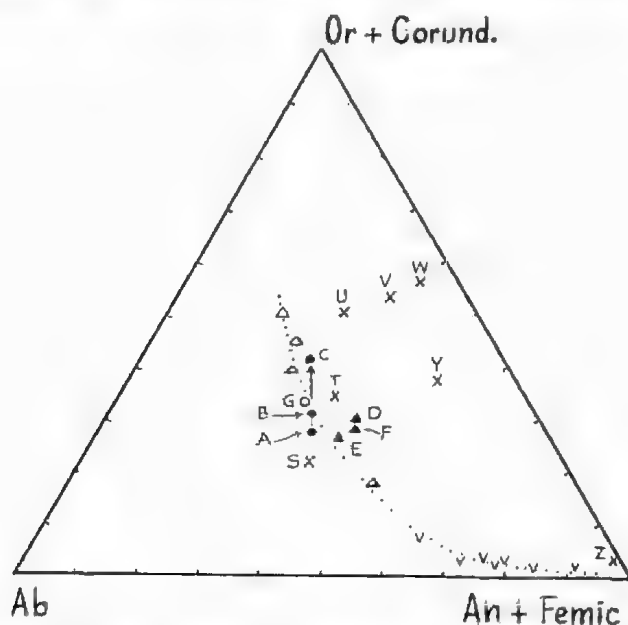


Fig. 6.—Diagram to show variation of normative orthoclase + corundum, albite, and anorthite + femic minerals in certain groups of Central Australian granites, and related granulites. The spots represent *orthopyroxene-bearing granites* (A = 30789, B = 30385, C = 30558). The solid triangles represent related *hornblende-bearing granites* (D = 30604, E = 30210, F = 34568). The circle represents the *Kulgera Adamellite* (G = 30138). The triangles represent associated *acid granulites* (30726, 30829, 30674, 30521 — numbered from top to bottom). The V's represent associated *basic granulites* (30730, 30581, 30840, 30638, 30639, 30543, 30230 — numbered from left to right). The crosses represent average *sediments* (S = greywacke, T = mica schist, U = phyllite, V — shale — Brammall, W = shale — Pettijohn, Y = sandstone, Z = limestone.

means of displaying the feldspar ratios of groups of rocks they can be misleading if too much petrogenetic significance is placed on them. Much better impressions are obtained from Larsen triangular diagrams, but even these must be carefully studied before the true significance of "trends" is decided.

### SUMMARY OF THE MAIN CHEMICAL FEATURES OF THE GRANITES

Notwithstanding the similarity of the orthopyroxenic and non-orthopyroxenic granites there are some significant chemical differences.

In Table 4 the percentages of the oxides of the three analyses of orthopyroxenic granites (A) and of the four related non-orthopyroxenic granites (B) are contrasted (the sheared garnetiferous granite from Upsan Downs (30397) omitted from Tables 4-6). The main features are:

*a.* The ranges of $SiO_2$, $Al_2O_3$, $TiO_2$ and MgO are about equal in both groups.

*b.* BaO shows a small but marked preference for the orthopyroxenic rocks, notwithstanding that normative orthoclase is comparable in both groups of granites.

*c.* $P_2O_5$ is high in all of these rocks, but is higher in the rocks rich in hornblende and biotite.

*d.* $K_2O$ tends to be slightly more plentiful in the orthopyroxenic granites, and $K_2O > Na_2O$ in both orthopyroxenic and non-orthopyroxenic granites. Note, however, that if cation % (rather than weight %) is considered, K is almost equal or slightly less than Na in both types of granite (see Table 6).

*e.* Although the range of CaO, and the An content in normative plagioclase tend to be higher in the rocks free from orthopyroxene, the range of An content in the modal plagioclase is about equal in both types of granite.

TABLE 4

A comparison of the main chemical features of some of the granites from Central Australia

| Weight% | Comparison | Orthopyroxenic granites (A)—variation in 3 | Non-orthopyroxenic granites (B)—variation in 4 |
|---|---|---|---|
| | | Weight% | Weight% |
| $SiO_2$ | $A \approx B$ | 63·52-66·96 | 61·48-66·20 |
| $TiO_2$ | $A \approx B$ | 0·84- 0·97 | 0·69- 1·16 |
| $Al_2O_3$ | $A \approx B$ | 14·32-16·76 | 14·79-16·07 |
| $Fe_2O_3$ | $B > A$ | 0·96- 1·81 | 2·68- 3·98 |
| FeO | $A > B$ | 3·85- 4·16 | 2·72- 3·75 |
| $Fe_2O_3 + FeO$ | $B > A$ | 4·93- 5·97 | 5·42- 7·27 |
| $\dfrac{FeO + MnO}{FeO + MnO + Fe_2O_3}$ | $A > B$ | 0·70- 0·81 | 0·47- 0·58 |
| Of in CIPW norm orthopyrox. | $A > B$ | 61·3 -69·1 | 25·4 -59·2 |
| MnO | $B > A$ | 0·09- 0·23 | 0·18- 0·32 |
| MgO | $A \approx B$ | 0·91- 1·24 | 0·92- 1·38 |
| CaO | $B > A$ | 2·06- 4·51 | 3·24- 4·77 |
| An in CIPW norm plagio. | $B > A$ | 26·8 -33·4 | 31·7 -44·1 |
| An in modal plagio. | $A \approx B$ | 29 -39 | 26 -37 |
| BaO | $A > B$ | 0·12- 0·16 | tr - 0·04 |
| $Na_2O$ | $A > B$ | 2·73- 3·88 | 2·54- 3·18 |
| $K_2O$ | $A > B$ | 4·01- 5·14 | 3·58- 4·30 |
| $H_2O+$ | $B > A$ | 0·04- 0·14 | 0·05- 0·26 |
| $P_2O_5$ | $B > A$ | 0·33- 0·52 | 0·55- 0·85 |

*f.* The most obvious difference is in the state of oxidation of the iron. Although the orthopyroxenic granites are somewhat lower in combined $Fe_2O_3$ and FeO than the granites free from orthopyroxene, they are much richer in FeO. The difference in state of oxidation of the two groups of granites is further emphasized in Table 4 by the contrast in the ratio $\dfrac{FeO + MnO}{FeO + MnO + Fe_2O_3}$ and in normative orthopyroxene.

In Table 5 an interesting relation is suggested between geographic location and the content of iron oxides (here expressed as cations—see also Table 6) in the granites. From Ernabella in the west to Kulgera in the east the granites tend to become less orthopyroxenic and increasingly hornblendic and biotitic, and, chemically, there is a general increase in the state of oxidation of iron from west to east. The basement gneisses and granulites, moreover, tend to change in facies from granulite to amphibolite from west to east.

An important conclusion from the chemical data of Tables 4 and 5 is that the orthopyroxenic rocks are in a lower state of oxidation than the hornblendic and biotitic rocks. On increase in $P_2O_5$ (and presumably F, since the $P_2O_5$ is fixed in these rocks as fluorapatite), and on slight increase in $H_2O+$, the Fe has become increasingly oxidized. These features are independent of the $SiO_2$

content. It is suggested that the availability of oxygen was an important factor controlling the formation and stability of the orthopyroxenic granites. The lack of any significant difference in the total oxygen content of the orthopyroxenic and non-orthopyroxenic rocks is interesting but not disturbing (see Table 5). It should be remembered that the small but significant changes in oxidation

TABLE 5

The variation in state of oxidation of iron in the granites, arranged in order from west to east.

| | | Cation ratio $\dfrac{Fe^3+Mn^2}{Fe^2+Mn^2+Fe^3}$ | Cation % $Fe^2+Mn^2+Fe^3$ | Oxygen no. for 100 cations |
|---|---|---|---|---|
| 30789 | Ernabella | ·825 | 3·83 | 163·4 |
| 30385 | Ombagunda | ·726 | 4·71 | 166·0 |
| 30558 | Spinifex Hill | ·718 | 4·51 | 167·5 |
| 30604 | Bald Hill | ·608 | 4·90 | 167·7 |
| 30210 | Alcurra Hill | ·599 | 5·29 | 166·0 |
| 34568 | Ayers Ranges | ·493 | 5·62 | 165·2 |
| 30138 | Kulgera | ·557 | 4·33 | 167·1 |

state of the iron are masked by variations of little or no petrological significance in some of the more abundant cations. Thus, $Si^4$ and $Al^3$ between them hold about 150 out of a total of 167 oxygen ions whereas $Fe^2$ and $Fe^3$ between them hold only about 5 or 6 oxygen atoms (readily calculated from cation % — see Table 6). In basic rocks, however, the change of valence of Fe shows a more significant change in oxygen distribution among the cations of the rock.

TABLE 6

Ion Percentages in Granites

| Ion | Orthopyroxenic | | | Non-orthopyroxenic | | | |
|---|---|---|---|---|---|---|---|
| | 30789 | 30385 | 30558 | 30604 | 30210 | 34568 | 30138 |
| Si | 59·16 | 62·25 | 63·54 | 61·80 | 60·19 | 58·48 | 62·56 |
| Ti | 0·52 | 0·62 | 0·69 | 0·49 | 0·80 | 0·83 | 0·60 |
| Al | 18·40 | 16·00 | 16·02 | 17·13 | 17·09 | 18·02 | 16·47 |
| Fe³ | 0·67 | 1·29 | 1·27 | 1·92 | 2·12 | 2·85 | 1·92 |
| Fe² | 3·09 | 3·29 | 3·06 | 2·79 | 2·98 | 2·62 | 2·15 |
| Mn | 0·07 | 0·13 | 1·18 | 0·19 | 0·19 | 0·15 | 0·26 |
| Mg | 1·26 | 1·74 | 1·58 | 1·36 | 1·58 | 1·96 | 1·30 |
| Ca | 4·50 | 3·27 | 2·09 | 4·51 | 4·44 | 4·86 | 3·28 |
| Ba | 0·04 | | 0·06 | | 0·015 | | 0·015 |
| Na | 7·01 | 6·10 | 5·02 | 4·69 | 5·81 | 5·20 | 5·83 |
| K | 4·76 | 5·01 | 6·22 | 4·51 | 4·33 | 4·36 | 5·18 |
| P | 0·41 | 0·30 | 0·27 | 0·61 | 0·44 | 0·68 | 0·45 |
| (OH) | 0·80 | 0·88 | 0·26 | 0·88 | 0·32 | 1·64 | 0·94 |
| O for 100 cations | 163·4 | 165·98 | 167·54 | 167·71 | 166·03 | 165·18 | 167·09 |

## RELATION OF THE GRANITES TO METAMORPHIC FACIES

### ORTHOPYROXENIC GRANITES

The *country rocks* in the vicinity of these granites are rocks of granulite facies. Details of these rocks are set out elsewhere (Wilson, 1954b, vol. 2).

Sphene is absent, and where hornblende is present it is the dark brownish, hastingsitic type which appears to be stable in rocks of granulite facies. Where

garnet occurs it is the typical garnet of granulite facies (a pyrope-almandine, very deficient in spessartite, with n = 1.772 to 1.796, and MnO = 0.50% to 0.81%).

*The granites* themselves show many features in common with charnockitic rocks from several parts of the world. They are composed essentially of andesine, K-feldspar, quartz, orthopyroxene, clinopyroxene and iron ores. Hornblende and biotite may be present, but are relatively late magmatic minerals. However, pyroxenic xenoliths are partly converted to hornblende, thus indicating that the "magma" was not as dry as has sometimes been supposed. The hornblende is more ferriferous than that of the granulites, but is not the green hornblende so commonly found in rocks of amphibolite facies. Sphene is absent. The potash feldspar is a moderately microperthitic orthoclase or non-twinned microline, and is not fluorescent (Wilson, 1950b, p. 229).

In *the metamorphic aureole* garnet and cordierite-bearing rocks are developed in a narrow zone near most contacts of the orthopyroxenic granite in the Ernabella region. The garnet is not the spessartitic almandine so commonly found in metamorphic rocks of amphibolite facies. The known range of refractive index (n) is 1.781 to 1.794. This suggests that the granite was emplaced under P,T- conditions equivalent to at least the lower grades of granulite facies. However, the co-existence of cordierite and "granulite" garnet in rocks which appear to be isofacial with rocks containing "granulite" garnet and hypersthene is possibly explained in terms of a more purely "thermal" metamorphism, whereby some of the features of the pyroxene hornfels facies (namely, co-existence of cordierite and hypersthene) have been superimposed on rocks of granulite facies. Indeed, the thermal metamorphism of "dry" metamorphic rocks by a fairly "dry" granite could be expected to produce rocks having features in common with both the granulite facies and the pyroxene hornfels facies.

The *associated pegmatites* of the orthopyroxenic granites contain hornblende, biotite, sphene, allanite and spessartitic garnet (n = 1.817). Such an assemblage is foreign to rocks of granulite facies, but is stable in amphibolite facies. This suggests that, although the parent orthopyroxenic granite could have been emplaced under "granulite metamorphic conditions", the associated pegmatites formed under the lower P,T- conditions of amphibolite facies.

### SPHENE-HORNBLENDE-BIOTITE GRANITES

The *country rocks* in the vicinity of these granites belong to amphibolite facies. Details of these rocks will appear in subsequent publications dealing with the Ayers Ranges and Kulgera Hills. Sphene-bearing gneisses, cordierite-spessartitic almandine-sillimanite gneisses, and amphibolitic rocks rich in a bluish green hornblende (γ = 1.690) are characteristic rocks. The spessartitic-almandines have n = 1.807, and MnO = 11.0%. These mineral assemblages are unstable in granulite facies, but stable in certain portions of amphibolite facies.

The *granites* themselves are devoid of orthopyroxene, and clinopyroxene occurs only as relics heavily corroded by a bluish green hornblende (γ = 1.692, 2V/α =55°, γ ∧ c - 19°), which is, in turn, heavily corroded by biotite. Sphene is common and the potash feldspar (microcline) fluoresces pink under short-wave ultra-violet radiation.

*The associated pegmatites* of these granites contain muscovite, beryl, tourmaline, biotite, microcline, and a spessartitic garnet with n = 1.817.

These features suggest that both the parent sphene-hornblende-biotite granite and end-phase pegmatitic material were emplaced under "amphibolite metamorphic conditions".

### Hornblendic Granites of Intermediate Type

Between the two extremes of the orthopyroxenic granites and the granites containing sphene and biotite there are many granites which are hornblendic but contain neither orthopyroxene on the one hand, nor sphene on the other. The hornblende is not the bluish green type noted above, nor the common green type. It is rather a brownish green type, in some respects similar to that found in certain metamorphic rocks of the granulite facies, but in other respects it is somewhat like the hornblende of the orthopyroxenic granites. The country rocks are difficult to place in facies as there are portions which may be taken as typical of the granulite facies, and others where characteristics of the amphibolite facies appear.

It is thus concluded that the granites described in this paper may be taken to be largely isofacial with their country rocks. The orthopyroxenic "igneous" rocks were emplaced under P,T- conditions comparable with (but probably a little lower than) those which produce typical metamorphic rocks of the granulite facies. The granites containing sphene and blue-green hornblende were emplaced under P,T- conditions comparable with those which produce certain high grade rocks in the amphibolite facies. The normal hornblendic granites, however, were probably emplaced under P,T- conditions capable of producing metamorphic rocks intermediate in many features between those of the granulite facies and the amphibolite facies.

## THE PETROLOGICAL SIGNIFICANCE OF CERTAIN MINERAL REACTIONS

### Replacement of Orthopyroxene, Clinopyroxene and Iron Ore by Hornblende

Replacement of orthopyroxene by clinopyroxene, and replacement of pyroxene by hornblende are reactions commonly of considerable importance in the metamorphic rocks which are associated with the granites under discussion in this paper. The latter phenomenon usually represents a fixation of certain components such as water, Na, Ca and F from migrating metasomatizing agents.

Since similar reactions are also common in the associated granites, some petrologists may be tempted to favour a hypothesis of metasomatic emplacement for the granites. However, the field evidence for magmatic emplacement of these rocks is more easily satisfied by considering that many of the reactions are due to concentration of end-phase liquors, as is the case in most normal igneous rocks. This is suggested by the fact that xenoliths of hypersthene-augite-labradorite granulite in orthopyroxenic granite are found to be impregnated with biotite, fluorapatite, potash-feldspar and hornblende, and rimmed with a sheath of brown hornblende. Thus the orthopyroxenic granite contained sufficient "end liquors" to carry out considerable corrosion of basic xenoliths. On the other hand, the orthopyroxenic granites cannot be considered to be rich in volatile components, for they have had little metasomatizing effect on the wall rocks, and they contain only small quantities of minerals normally associated with the end-phase of normal igneous rocks.

In hornblende-rich granites pyroxene is found to be more completely replaced by hornblende, and apatite, biotite, calcite and late quartz are more important than in the orthopyroxenic granites. In the biotite-rich granites sphene and fluorite may be additional end-phase minerals. These reactions are probably strongly influenced by the availability of oxygen as well as of fluorine and water.

### Corrosion of Plagioclase by K-Feldspar

Corrosion of plagioclase appears to have taken place in at least three ways, resulting in the development of micro-antiperthite, microperthite, and an extensive replacement of shattered and bent plagioclase (see Plates 2, 3 and 4).

*Micro-antiperthite.*—The irregular development of micro-antiperthite appears to be confined in some rocks to those portions most affected by the same stresses which controlled the formation of twinning. In some granites (as in some of the basement granulites) it would even appear that the K-feldspar lenses tend to be localized in "potential" tension gashes in the newly formed twin-lamellae. While it is possible that the shearing may have initiated exsolution of dissolved K-feldspar only in those zones most affected by the shearing, it is thought that it is more likely that the structural weaknesses, such as developing twin-planes and potential tension gashes, have merely assisted to localize the replacement of the plagioclase by migrating K-feldspar or its equivalent ions. True exsolution micro-antiperthite has not been recognized in these rocks.

*Microperthite.*—In some rocks microperthite has been developed by the replacement of plagioclase by K-feldspar. The replacement of plagioclase has been so extreme that it is difficult to decide which is the host and which is the included mineral. Pl. 4, Fig. 1 shows how such a microperthite can sometimes be developed from micro-antiperthite. This is identical with a phenomenon described from the basement granulites of the Musgrave Ranges (see Fig. 28, Wilson, 1954b, vol. 2, p. 92).

*Extensive replacement of bent and shattered plagioclase crystals.*—This is one of the most common replacement phenomena found in these granites. In almost all cases the twin-lamellae are bent and shattered. The petrographic evidence is clear that the twinning and distortion took place at about the same time, and it appears that the twinning itself has been largely developed by shearing. In the associated granulites and gneisses, identical bending and shattering of plagioclase grains appear to have gone on at the same time as potash-feldspathization. Not only has K-feldspar replaced plagioclase in the solid state, but euhedral fluorapatite crystals are commonly found in such positions within embayments of the plagioclase that they must represent a fixation of P and F by some of the Ca expelled from the plagioclase. For replacements of this type, K, Si, P and F were necessary. Such reactions seem to have taken place during a period of shattering and upwarp, or even of active folding which has been superimposed on the products of a metamorphism which took place under P,T- conditions characteristic of the granulite facies. This is suggested by the fact that in the granulites the plagioclase grains tend to be poorly twinned in most of those rocks where bending of (010) cleavages (and twin-lamellae) and K-feldspathization are not well developed. It is well known that plagioclase is very poorly twinned in many rocks of the granulite facies. Development of un-bent clinopyroxene from the corrosion of bent orthopyroxene and fixation of Ca expelled from replaced bent plagioclase, and the development throughout the rock of irregular cracks filled with bands of magnetite, emphasise that considerable metasomatic adjustments have taken place in many of the original granulites during or just after a period of folding or warping.

All of these features are also common in the granites which appear to inject the granulites. How, then, can the granites be magmatic, for wherever similar phenomena are present in the granulites it is clear that the reactions have gone on in *situ* in the solid state? This is a question of fundamental importance, and must now be discussed.

Corrosion of plagioclase by K-feldspar is well known as a late phase of crystallization of silicate melts. This phenomenon is often attended by corrosion and replacement of orthopyroxene by clinopyroxene, clinopyroxene by hornblende, hornblende by biotite, and by crystallization of late apatite, calcite, quartz, iron ores and certain other accessories. Since these mineralogical reactions are all developed in varying degrees in most of the granites of the area
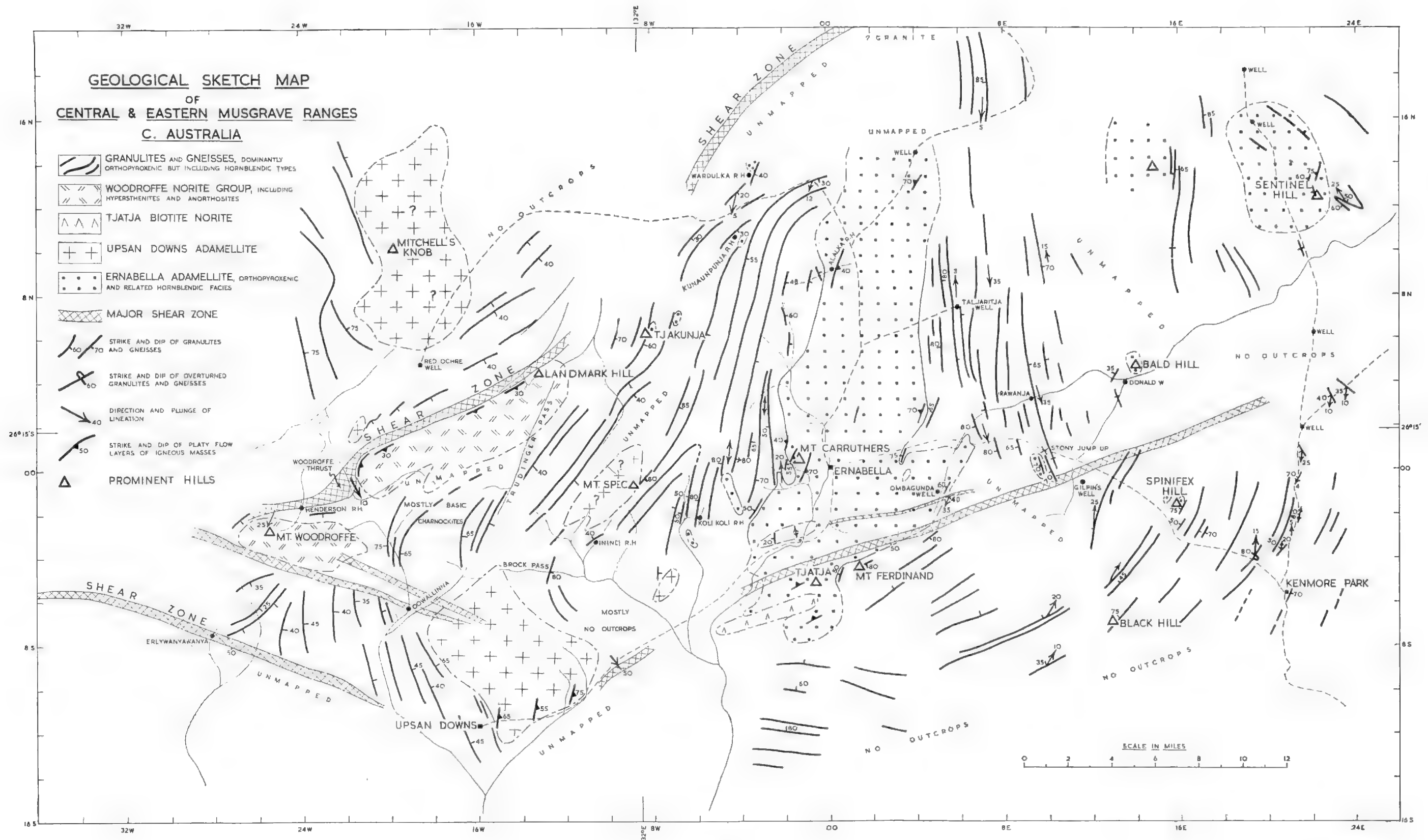
Fig. 7

one could argue a magmatic origin and emplacement of these granites. While it is true that such reactions do occur, certain grave textural anomalies appear if such a view is accepted without modification.

If corrosion of plagioclase took place in a potassic *liquid*, a grain would be gradually disintegrated, and, before completely dissolving, may be expected to drift apart as corroded microxenocrysts with random orientation. Bending and fracturing of the crystals could take place during corrosion by the liquid but only if there were a small amount of intergranular liquid, for free-floating crystals cannot be bent. If it can be demonstrated that distortion of crystals took place during their corrosion the phenomenon could perhaps be called a protoclastic structure.

In the granites under discussion, however, the corroding K-feldspar could scarcely have been merely an intergranular liquid for the following reasons:

(1) The sheath of K-feldspar is usually much too wide to have allowed protoclastic bending and shattering to go on during corrosion by K-feldspar.

(2) Relics of plagioclase have not drifted apart as they would in liquid. In many cases the plagioclase has clearly been replaced *in situ*.

It is thus concluded that the extensive replacements of bent and broken plagioclase crystals would appear to favour a metasomatic mode of emplacement of the granites. A suggested reconciliation of the field and laboratory evidence concerning origin and mode of emplacement of these granites is set out under "Conclusions".

## AGE OF THE GRANITES

The granites and intruded gneisses and granulites of the Musgrave Block are presumed to be of Precambrian age. Almost unmetamorphosed Upper Proterozoic sediments of the Adelaide System are reported to lie unconformably upon the Precambrian gneisses east of the Everard Ranges (Jack, 1915, figure facing p. 46). Tillites have been recorded in these sediments (Wilson, 1952c).

Since dolerite dykes are found cutting both the gneissic complex and the granites of the Everard Ranges yet have not been found cutting the Upper Proterozoic sediments, it is presumed that the granites of the Everard Ranges are Pre-Upper Proterozoic in age. Similar dolerites cut the granites in the Ayers and Musgrave Ranges, hence an early Precambrian age for the granites of the Musgrave Ranges is reasonable on the evidence at present available (Wilson, 1948).

## CONCLUSIONS

Two major problems have become evident in this study. One is the petrological relation between the granites, and the granulites and gneisses; the other is the structural relation between the granites, and the granulites and gneisses. These are problems because there is strong petrographic evidence that the granites have been derived from the granulites and gneisses by metasomatism, but there is equally strong field and petrographic evidence that the granites were magmatically emplaced. Moreover, some of the most important granites are more or less meridionally-trending masses which are set within more or less meridionally-trending granulites and gneisses, and yet, when they are considered regionally, they are distributed geographically as an E.-W. string of granites rather than as a N.-S. string.

Consideration of these two allied problems raises many side issues of importance, but much more field work must be done before these can be discussed with profit.

## PETROLOGICAL RELATION BETWEEN THE GRANITES AND THE
### BASEMENT GRANULITES AND GNEISSES

Three main hypotheses may be brought forward to explain the origin of the granites and their relation to the basement rocks. The hypotheses emphasize (respectively) the role of metasomatism, or of a silicate melt, or of mobilization of a reconstituted basement. None of these hypotheses indicates the ultimate cause of the granite formation, and the favoured hypothesis (mobilization of a reconstituted basement) is to be looked upon as one which should stimulate more fundamental geochemical research. Moreover, it will be noted that some of the evidence which is listed under a particular hypothesis is not strong, and is capable of other interpretations.

*Metasomatism hypothesis—features which could support the hypothesis of the formation of the granites in situ by metasomatism.*

Petrographic evidence:

a. K-feldspathization of plagioclase on a scale larger than is normally seen in an end-phase magmatic liquid (see p. 69).

b. Replacement of plagioclase by hornblende in some granites.

c. Zircon is of one type in the granites, whereas many of the basement granulites contain a suite of zircons as in meta-sedimentary rocks. In some granulites, however, a complex zircon suite would appear to be in process of homogenization. Poldervaart and von Backström (1949, p. 467) give some evidence that zircon may undergo granulation and recrystallization by ultra-metamorphism of a grade higher than the sillimanite zone.

Field evidence.—Nil.

*Silicate-melt hypothesis—features which could support the hypothesis that the granites crystallized from a fairly pure silicate melt.*

Petrographic evidence:

a. Orthopyroxene and hornblende are notably different from those of the intruded basement.

b. An order of crystallization for the mafic minerals (commonly orthopyroxene, followed in order by clinopyroxene, hornblende and biotite) is the same as that of basic magmas.

c. Zircon is of one type in the granites, whereas many of the basement granulites contain a suite of zircons as in meta-sedimentary rocks.

d. Occasional phenocrysts of non-zoned andesine (almost identical in orthopyroxenic and non-orthopyroxenic granites) may be found throughout the whole area. (But note that similar, though smaller, non-zoned andesine grains are common in the basement granulites of comparable composition. Moreover, there is evidence that many of these grains have developed in the granulites in a manner comparable with the growth of K-feldspar porphyroblasts. Thus, it could be argued that the occasional phenocrysts in the granites do not necessarily support the silicate-melt hypothesis, for the phenocrysts could be relics of andesine porphyroblasts which grew during a metamorphic phase prior to mobilization of the granite magma).

Field evidence.—Xenoliths (sheathed with hornblende) are alined parallel to transgressive contacts with the basement granulites. Xenoliths are uncommon in areas away from the contacts.

Surrounding the masses of orthopyroxenic granite there is an aureole in which cordierite and pyrope-almandine co-exist in the basement rocks of appropriate composition. The basement rocks are elsewhere dominantly granulite facies. Similar aureoles, but at a slightly lower temperature range, surround the clinopyroxenic, hornblendic and biotitic granites.

*Mobilization hypothesis — features which could support the hypothesis that the granites were formed by mobilization of a magma produced by reconstitution of the basement pyroxenic granulites.*

(This is the hypothesis favoured in this paper.)

Petrographic evidence:

a. Zircon. This is non-zoned and of one type, whether found in ortho-pyroxenic, hornblendic or biotitic granites. It appears to be a fairly "early mineral" in the granites. If the zircon has been formed by homogenization and recrystallization of heterogeneous suites of zircons in the basement rocks the process would need to have been very efficient, for no evidence of "original" zircons has been found in the granites themselves. Poldervaart and von Backström (1949, p. 467) bring forward some evidence that complete recrystallization of this sort can go on during the formation of granite by "ultra-metamorphic" processes.

b. K-feldspathization. Replacement of bent and shattered plagioclase by K-feldspar is common in both granites and basement rocks, but is more consistently developed and is generally more effective in the granites. The development of these and other K-feldspar replacement phenomena (as discussed on p. 68) is strong evidence for a replacement origin of the granites (as pointed out above). However, it must be remembered that the hypothesis now under discussion also requires widespread reconstitution of the basement rocks. Indeed, the act of mobilization itself is thought to be largely controlled by more intense "flooding" of the reconstituted basement rocks (in structurally favourable positions) by ions of K, P and F. In a sense, some of the more extensively replaced shattered plagioclase grains may be looked upon as a result of corrosion of the rheomorphic crystal mush by the K-rich "lubricant".

c. Fluorapatite. Euhedra of fluorapatite commonly have been formed by the fixation of P and F by Ca in process of being displaced from plagioclase during K-metasomatism.

d. Orthopyroxene. In the granites orthopyroxene is consistently much more ferriferous than the orthopyroxene of both acid and basic basement rocks. Moreover, the Fe content of the orthopyroxene is not linked with the $SiO_2$ or alkali content of the granites. However, the orthopyroxene of the granites is thus not merely xenocrystal orthopyroxene from the basement rocks, as in some granites (e.g., Wilson, 1958a, p. 39). From theoretical considerations, one would expect the magma which has been produced by partial melting of the basement to contain mafic minerals which are more ferriferous than those of the basement, if for no other reason than that ferrous silicates have a lower melting point than corresponding magnesium silicates. The differences in composition (determined optically) of the co-existing pyroxenes of the granites and of the basement granulites (Fig. 3) may be explained if the orthopyroxenic granites resulted from palingenetic magma produced by partial melting of the basement in structurally favourable positions. If a palingenetic granite magma were formed from crustal or geosynclinal rocks rich in volatiles the mafic minerals would probably be biotite or hornblende. These, too, should be richer in Fe than corresponding mineral phases in the original rocks. If palingenetic granite magma were produced by partial melting of igneous or metamorphic rocks which are low in volatile content (such as pyroxene granulites) pyroxenes are likely to be prominent among the new mafic minerals. Moreover, the mafic minerals may be expected to be more ferriferous than corresponding mineral phases in the original rocks. Thus, it is significant that in Central Australia the orthopyroxene of the orthopyroxenic granites and the hornblende of the horn-

blendic granites are more ferriferous than corresponding mafic minerals of the basement gneisses and granulites.

Possibly due, in large measure, to an increase in availability of oxygen in the areas undergoing injection, orthopyroxenic granites appear to have given way to clino-pyroxenic and hornblendic granites. All of these types of granite may be found in a single restricted area, e.g., Sentinel Hill. This emphasizes the genetic unity of the long E.-W. string of granites which range from ortho-pyroxene granites in the Musgrave Ranges through augite-biotite granites in the Ayers Ranges and Kulgera Hills.

Field evidence.—As for the silicate-melt hypothesis.

## STRUCTURAL RELATION BETWEEN THE GRANITES AND THE GRANULITES AND GNEISSES

Extensive field work must precede the explanation of the apparent contradiction of the long E.-W. string of petrologically closely-related magmatic granites, many of which form N.-S. bodies sub-parallel to the major fold structures of the basement rocks. An origin of the granites by an orthodox geosynclinal-disintegration mechanism is difficult to substantiate. The weight of available evidence is that the granites here described may have been formed by a reconstitution of the basement rocks (now represented by hypersthenic or hornblendic granulites of many types). It is suggested that a regional deep-seated E.-W. downwarp (possibly associated with deep-seated E.-W. trans-current shearing) may have been sufficient to have caused thorough reconstitution of the basement rocks, and to have produced "pockets" of potential magma in favourable areas. Subsequent emplacement of the resultant rheomorphic masses would be assisted by pre-existing weaknesses due to the N.-S. attitude of many of the original rocks.

This may explain the E.-W. string of granites which are often found within rocks of N.-S. tectonic trend and could throw light on some of the lineation problems in parts of Central Australia (see Wilson, 1953b, 1954a, 1959a). E.-W. downwarping is not tectonically foreign to this portion of Australia. There have been some major E.-W. downwarpings and archings immediately to the N. and possibly to the S. of the Musgrave Block. The Amadeus Trough seems to be the relic of downwarping and other crustal disturbances which later became the basin for sedimentation ranging from late Proterozoic to at least Ordovician. It is not suggested, however, that the Amadeus Trough *as such* has had anything to do with the origin of the granites under discussion, but there seems to be evidence that there has been a very early E.-W. crustal weakness in this area which may have been the ultimate cause of the granite formation.

## THE SIGNIFICANCE OF THE GRANITES IN THE CHARNOCKITE PROBLEM

A superimposed metamorphism (which is essentially thermal and metasomatic rather than dynamic) could be responsible for some of the puzzling features of charnockitic rocks. For example, the granulose texture of many of the basic granulites associated with these granites is remarkably like that produced by prolonged thermal metamorphism of dolerite. Regional downwarp on E.-W. axes may have first developed rocks of granulite facies (or upper levels of the amphibolite facies) from metamorphic or igneous rocks which, many millions of years previously, had suffered their original metamorphism or injection. These have undergone intense granulation in structurally unstable zones (e.g., near zones of "plastic shear" which would represent fault zones at

higher structural levels), and recrystallization elsewhere. In favourable zones the orthopyroxenic granites were developed by a reconstitution of the basement rocks.

The restriction of orthopyroxenic granites to areas where the associated rocks are dominantly of granulite facies, and the restriction of hornblende granites and sphene-bearing granites to areas within the amphibolite facies suggest that the metamorphism of the basement rocks and the generation of the granitic magmas are closely related phenomena. Moreover, on the up-rise of the mobilized "igneous" masses the basement rocks have suffered a further metamorphism (of relatively local extent). This is more akin to the conditions necessary to produce the rocks of pyroxene hornfels facies. As was seen on p. 66, rocks of granulite and pyroxene hornfels facies have much in common, mineralogically.

Whether or not the hypothesis of a downwarping of already metamorphosed rocks can be substantiated, there are some important facts which do emerge from the present study.

In the Musgrave Ranges charnockitic rocks of more than one origin have been found. The basement rocks are mostly hypersthene-bearing granulites and gneisses which are of granulite facies. They are metamorphosed sediments of various types, basic igneous rocks, and rocks which have been so affected by metasomatism that their original character is unknown. Moreover, some of the basement rocks show evidence of superimposed metamorphism whereby features of the amphibolite facies, or of the pyroxene hornfels facies, may appear.

The orthopyroxenic granites described in this paper may also be called charnockitic. These differ structurally from the charnockitic rocks of the basement rocks in that they have been magmatically emplaced. Although there are some important features of these magmatically emplaced rocks which owe their origin to metasomatic metamorphism, there are other important features which appear to have resulted from crystallization from a silicate melt, even though this may not have been any more than the interstitial material of the partly crystalline mush from which these charnockitic granites were formed.

These "magmatic" charnockitic granites, moreover, grade into augite granites, hornblende granites and even sphene-bearing biotite granites where the P,T- conditions (and possibly availability of oxygen and water) are more like those pertaining to the amphibolite facies than to the granulite facies.

Although these "magmatic" charnockitic rocks cover a large area of the Musgrave Ranges, charnockitic rocks of purely metamorphic origin (i.e., the basement granulites) are more important both there and elsewhere in Australia.

## ACKNOWLEDGMENTS

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# EXPLANATION OF PLATES

## PLATE 1

Fig. 1.—Sharp intrusive contact of the orthopyroxene-bearing Ernabella Adamellite and steeply-dipping charnockitic granulites ¾ mile SW. of summit of Mt. Carruthers, Musgrave Ranges. The adamellite contains a few dark bluish grey phenocrysts of plagioclase. The granulites do not appear to have been metamorphosed by the intrusion, which is here shown (in a cliff section) to have been emplaced above the granulites.

Fig. 2.—Sharp intrusive contact of orthopyroxene-bearing granite (bottom right) and garnet-bearing gneiss (top left). Large hammer-head is on contact (which has strike 300° and dip 80° S., i.e., parallel to the small hammer handle), and the handle of large hammer is approximately parallel to the strike of the gneisses (which have strike 340° and dip 40° W.). The granite is much finer-grained at the contact and shows rough platy-flow structure parallel to the contact. Looking NE. High up on S. wall of valley near Alalka rock-hole, Musgrave Ranges.

## PLATE 2

Fig. 1.—Elongate mafic clot composed of magnetite (black), ferrohypersthene and less common calcic augite (both dark grey), apatite (highly refringent white grains in mafic clot). Most of the salic minerals shown in this figure are poorly twinned grains of plagioclase. Ferrohypersthene granodiorite (30476), 2½ miles NNW. of Alalka rock-hole, Musgrave Ranges. Field of view: 4 mm. diam.

Fig. 2.—Shattered plagioclase crystal (white, on cross-wire quadrants 1 and 4) replaced by K-feldspar (dark grey). Note relics of plagioclase in K-feldspar. Most of the black areas in the plagioclase are K-feldspar. Apatite crystals are commonly associated with these corrosive patches of K-feldspar. Ferrohypersthene granodiorite (30476), 2½ miles NNW. of Alalka rock-hole, Musgrave Ranges. Crossed nicols. Field of view: 5 mm. diam.

Fig. 3.—Micro-antiperthite formed by replacement of andesine (twinned mineral forming the major portion of the field) by K-feldspar (dark grey irregular patches in the andesine). The patches of K-feldspar commonly contain grains of pyroxene (as in quadrant 1), apatite, zircon or iron ore. There is no lenticular micro-antiperthite in this rock. Note the healed shatter zone and the shears filled with iron ores crossing quadrants 3 and 4. Typical charnockitic granodiorite, No. 30789, Ernabella. Field of view: 5 mm. diam. Crossed nicols.

Fig. 4.—Texture of a typical charnockitic granodiorite, No. 30789, Ernabella. There is a tendency for alinement of the mafic clots, which are composed of ferrohypersthene (surrounded by calcic augite in upper part of quadrant 3), calcic augite (quadrant 3), iron ores, hornblende (surrounding iron ores in quadrant 2), and quartz, whether as granules (e.g., on the cross-hairs intersection) or as larger grains (e.g., in quadrant 2) have plentiful dust-like inclusions. Microperthite commonly encloses quartz granules (e.g., centre of figure). Plagioclase is shown in bottom of quadrant 3 (see also Plate 2, Fig. 3). There are shears filled with black iron ores in quadrant 4. Field of view: 4·5 mm. diameter.

Fig. 5.—Relics of corroded plagioclase (twinned) in K-feldspar (microperthitic). Attitude of relics suggests bending and shattering of plagioclase prior to replacement by K-feldspar (cf. Pl. 2, Fig. 4). Hornblende adamellite (30596), Bald Hill, E. Musgrave Ranges. Crossed nicols. Field of view: 5·4 mm. diam.

Fig. 6.—Relics of plagioclase (white) corroded by K-feldspar. Note crystal of apatite (dark grey needle near A) which occurs in tiny "pool" of K-feldspar introduced into the plagioclase. The round dark objects are bubbles in the thin-section. Augite-hornblende adamellite (34598), 8 miles WSW. of Victory Downs, W. Ayers Ranges, Central Australia. Field of view: 4·8 mm. diam. Crossed nicols.

## PLATE 3

Fig. 1.—Irregular development of micro-antiperthite due to replacement of plagioclase (white) by K-feldspar (light grey). K-feldspar content of some portions of the feldspar reaction complexes is such that all gradations may be seen from plagioclase through micro-antiperthite to micro-perthite. Very fine micro-perthitic lenses of albite (probably due to exsolution rather than to replacement) may be seen in the middle of most patches of K-feldspar (e.g., near cross-wires, and see Pl. 3, Fig. 2). Ferrohypersthene adamellite (30701), Tjakunja, Musgrave Ranges. Crossed nicols. Field of view: 2·8 mm. diam.

Fig. 2.—Very fine micro-perthitic inclusions (centre) in K-feldspar lens in micro-antiperthitic plagioclase. Enlargement of central portion of Pl. 3, Fig. 1. Crossed nicols. Field of view: 0·4 mm. diam.

## PLATE 4

Fig. 1.—Micro-antiperthite (quadrant 2) and microperthite (quadrants 3 and 1) both formed by metasomatism of a single plagioclase crystal. K-feldspar (K) has irregularly replaced plagioclase (P), and the small relics of plagioclase in quadrant 3 are clearly in optical continuity with the parent plagioclase mass. The plagioclase grain which is shielded by pyroxene from K-metasomatism (white grain, P, in quadrant 4) is not antiperthitic. Pyroxene is ferrohypersthene in which lamellae of diopside show as several vertical narrow white bands. Q = quartz. Ferrohypersthene adamellite (30700), near Tjakunja, Musgrave Ranges. Crossed nicols. Field of view: 3 mm. diam.

Plate 1



1



2

Plate 2

1

2

1
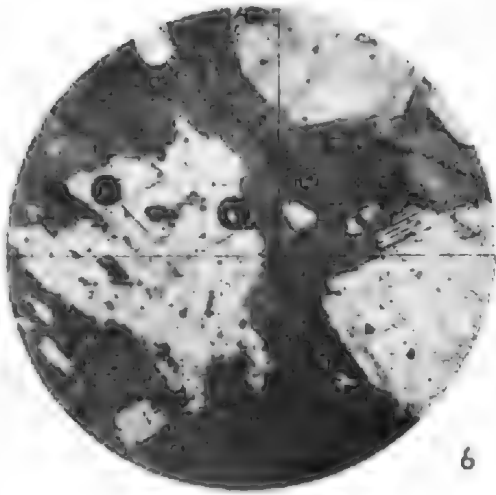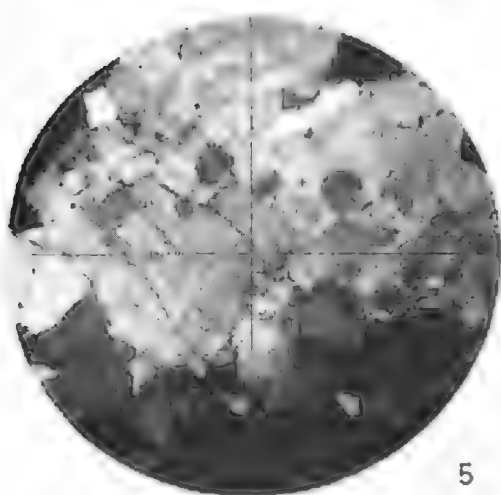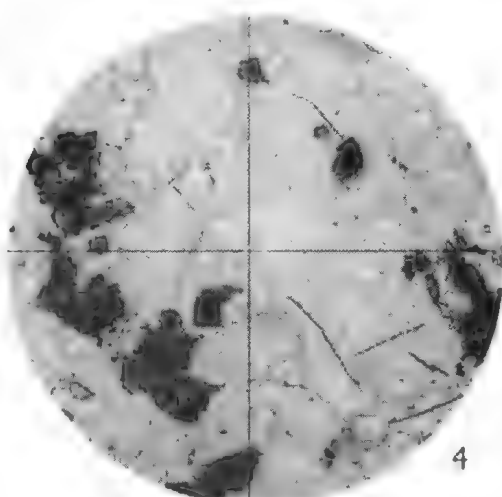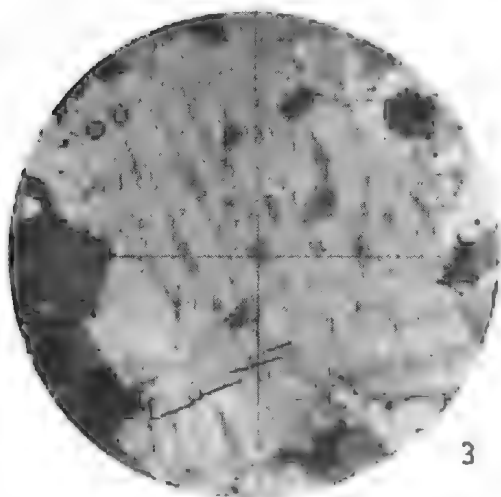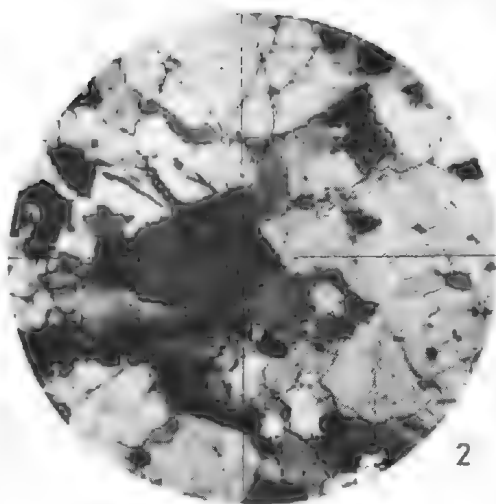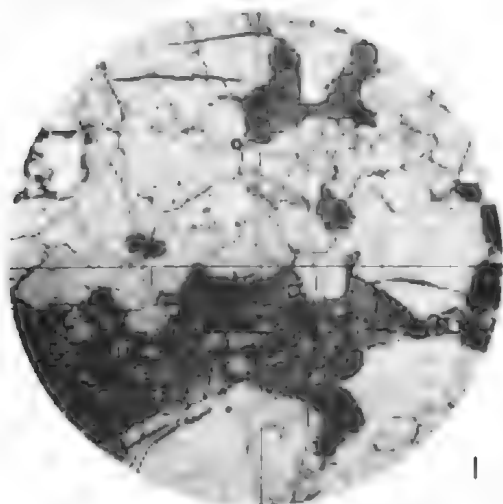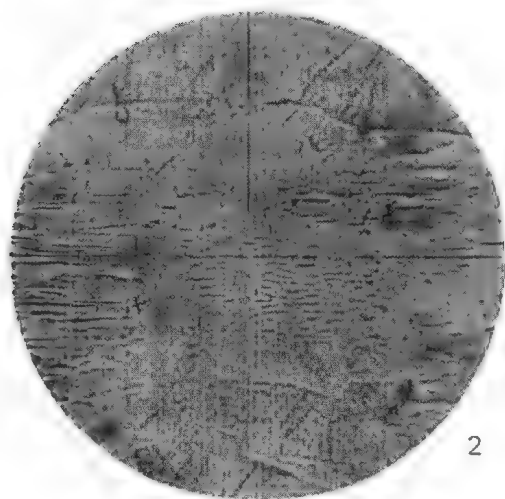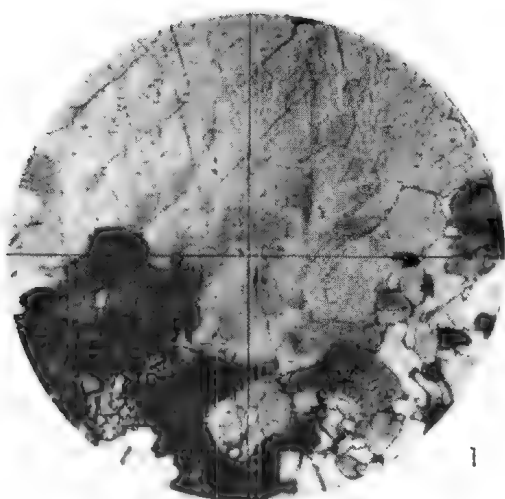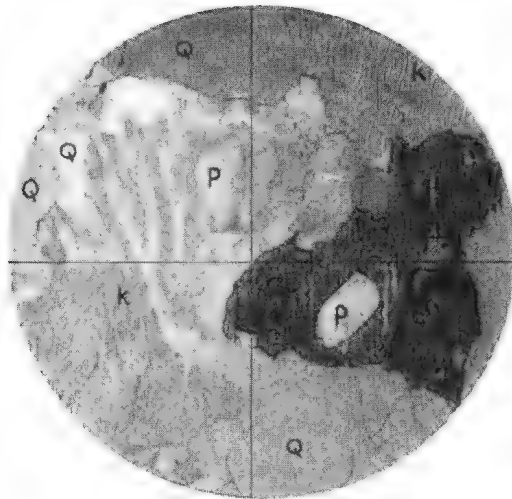
# AN ABERRANT SPECIES OF ECLIPTA FROM AUSTRALIA

BY R. MELVILLE

**Summary**

# AN ABERRANT SPECIES OF ECLIPTA FROM AUSTRALIA

## by R. Melville

### [Read 9 July 1959]

The composite described below was discovered by Mr. E. H. Ising on the Arkaringa Creek about 60 miles south of Oodnadatta. On examination it was seen to be a member of the *Heliantheae-Verbesininae*, but at first it did not appear to fit any hitherto described genus in this section of the family. The *Verbesininae* include a number of weedy species and it seemed likely that the plant was an adventive in Australia from some other part of the world. Accordingly, a search was made through the available material of the *Verbesininae* to determine whether the plant was an aberrant member of any of the recognised genera, either from Australia or elsewhere. It was found to resemble *Eclipta alba* (L.) Hassk. and *E. platyglossa* F. Muell. very closely in foliage, involucre and indumentum and the aspect of the capitula. A comparison of dissections of the several species of *Eclipta* with the new plant showed that all were very similar in floral morphology. However, the fruits differed strikingly in the possession of rather broad wings, as well as in a greater development of the pappus. They were similar to those of *Verbesina encelioides* (Cav.) A. Gray, which is in other respects widely different. This *Verbesina* is itself rather aberrant in its own genus in the possession of winged fruits, but it serves to draw attention to the existence of winged and wingless fruits in a number of composite genera. Sometimes, as in *Verbesina* the exalate forms predominate, at others, as in *Brachycome* alate forms are most abundant. Such variation is not, of itself, sufficient to warrant separation as a new genus, in the absence of other distinctive features and the conclusion was reached that the new plant should be assigned to *Eclipta*. No evidence was found that it occurs anywhere but in Australia.

ECLIPTA ALATOCARPA *Melville*, sp. nov., *E. platyglossae* F. Muell. affinis, sed dentibus papporum subulatis et acheniis late alatis differt.

Herba annua erecta ramosa 20-30 cm alta, caulibus scabridulis vel subglabris. Folia opposita vel interdum alternata, lanceolata, acuta, basibus cuneatis, supra et infra scabridula, laminae 15-35 mm longae, 5-10 mm latae, petiolis 5-12 mm longis munita. Capitula florifera 3-5 mm lata, in axillis foliorum, pedunculis 4-6 mm longis appresso-hirsutis; bracteae involucrorum 8-10, 1-2 seriateae, oblongo- vel ovato-acutae, scabridae, 5-6 mm longae, 1·5-3·0 mm latae, eae receptaculorum lineari-subulatae, circa 4-5 mm longae breve ciliatae; flores radiati ♀, circa 10, flavi, corollis ligulatis, emarginatis, 2·5-3·5 mm longis, 2 vel 3 nervatis; flores disci circa 20-25, hermaphroditi, tubi corollarum 1·5 mm longi, 4-lobati; ovaria oblonga, applanata, circa 2·5 mm longa, supra hirsuta et setis 2 vel 3 papporum coronata. Capitula fructifera 8-10 mm lata, cypselae flororum radiatorum tri-alatae, eae flororum discorum applanatae, obovatae, late bialatae, 4·5-5·5 mm longae, 3-4 mm latae, faciebus lateralibus papillis conicis vel irregularibus indutis.

South Australia: Arkaringa Ck., 12 mls. N. of Mt. Barry stn., 60 mls. S. of Oodnadatta, E. H. Ising No. 3766, Aug. 30, 1955 (K holo.; Adelaide, iso.). Queensland: S. Oestrus, Gilruth Plains, Coll. K. C. Baker. No. G830, March 7, 1949 (in Herb., Canberra).

During this investigation, a second collection, from the Gilruth Plains, was sent to me by Miss N. T. Burbidge. Both occurrences were of single plants so that the species may be scarce, though, with its undistinguished appearance, it may easily have been overlooked.
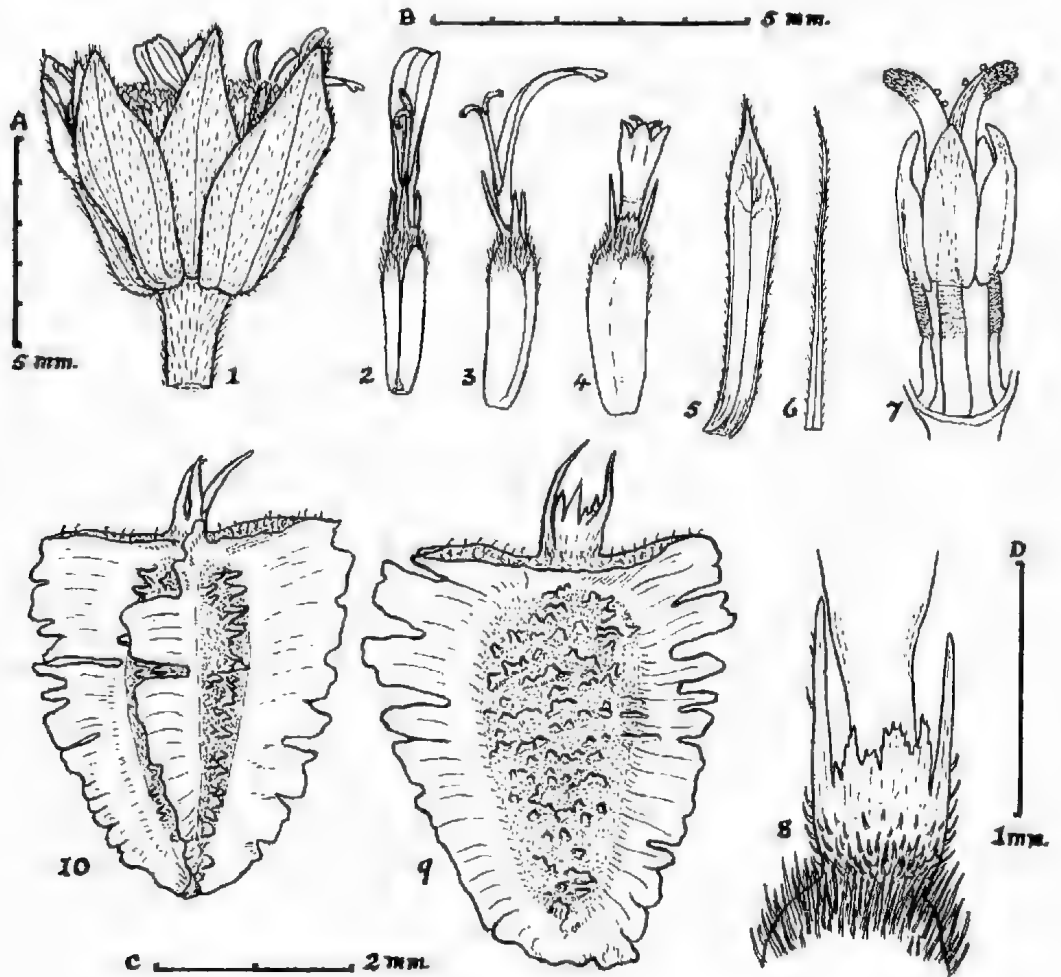


*Eclipta alatocarpa* Melville, sp. nov. 1, flowering capitulum, scale A; 2, 3, ray floret, adaxial and lateral views; 4, disc floret; 5, inner bract of involucre; 6, receptacular scale; 7, stamens and stigmas of disc floret; 8, pappus of disc floret; 9, fruit of disc floret; 10, fruit of ray floret. Figs. 2-6, scale B. Figs. 7-8, scale D. Figs. 9-10, scale C. Camera lucida drawings from the holotype.

# NOMENCLATURE OF NOTOMYS (MURIDAE) IN THE LAKE EYRE BASIN

*BY* H. H. F*INLAYSON*

**Summary**

# NOMENCLATURE OF NOTOMYS (MURIDAE) IN THE LAKE EYRE BASIN

### By H. H. Finlayson

### [Read 13 August 1959]

In identifying some recent collections of *Notomys* my attention has been directed again to the unsatisfactory state of the nomenclature of two of the species which are widespread in the arid districts of the State of South Australia and are particularly important numerically in the Lake Eyre Basin.

In 1939, in checking the results of my own field work in that area against the considerable series of *Notomys*, which had accumulated in the South Australian Museum from the same district, I was drawn to the provisional conclusion (for reasons fully stated in my subsequent paper), that *Notomys aistoni* Brazenor, 1934, was a colour phase only of *N. cervinus* Gould, 1853; this species is known to the local aborigines (Wonkanooroo) as oorarrie. A second species known as wilkintie, which I then considered to be the *N. cervinus* of Waite and Wood Jones and most modern authors, was thereby rendered innominate; but as any measures towards stabilization depended on a re-examination of the type of *N. cervinus* Gould in London, the matter was left in abeyance. No further factual evidence bearing on the subject was published until 1951, when Tate in his review of the genus, made this re-examination in relation to topotypes of *N. aistoni* and found sufficient agreement to substantiate my suggestion of 1939, and to relegate the latter to the synonymy of *N. cervinus* Gould.

The way was thereby opened for the recognition of the wilkintie in nomenclature, but this step was complicated by a doubt as to the real status of *Notomys fuscus* Wood Jones, 1925, of which no type was designated and of which only a single topotype of the Wood Jones series is available for study. Iredale and Troughton (Check List of Aust. Mammals, 1934) have already equated *N. fuscus* to *N. cervinus* of Gould, but it is not clear whether this finding was based on the Wood Jones series from Ooldea or on some of the several "dark forms" which have been recorded from other localities; their synonymy is, of course, no longer acceptable owing to the revolution in the conceptions of the real character of Gould's species (infra).

A critical re-examination of the above topotype of *N. fuscus* has convinced me of its specific identity with the Lake Eyre Basin wilkintie, but the question remains as to whether the differential characters relied on by Wood Jones (most of which show considerable variation in the Lake Eyre Basin) should be accepted at the sub-specific level or regarded merely as a phase of polymorphism of which there are already illustrations in the genus. The single specimen available is quite inadequate for a solution of this problem, which will depend ultimately on extended field work. Wood Jones, however, writes (1925) of having had numerous specimens from Ooldea and as he was evidently assured of the uniformity of *N. fuscus* at that place it may be accepted that the differential characters at least have a higher frequency at Ooldea than in the Lake Eyre Basin. I have therefore chosen the first alternative and now regard *N. fuscus* as being represented by two geographical forms based on these respective areas.

These conclusions may be summarised as follows:

## 1. NOTOMYS CERVINUS Gould, 1853.

*Hapalotis cervinus* Gould, 1853, Proc. Zool. Soc. London (1851), p. 127.
*Notomys cervinus* Thomas, 1921, Ann. Mag. Nat. Hist., 9 (8), p. 425, *et seq.* (lectotype).
*Podanomalus aistoni* Brazenor, 1934, Mems. Nat. Museum Melbourne, 8 (81), Pl. V, Fig. 8;
    Pl. VI, Fig. 5.
*Notomys aistoni* Finlayson, 1939, Trans. Roy. Soc. S. Aust., 63 (1), p. 103, Pl. IV, Figs. G,
    H and P; Pl. V, Figs. M, N and O.
*Notomys cervinus* Tate, 1951, Bull. Am. Mus. Nat. Hist., 97 (4), p. 262.

A species of medium size, with no gular pouch, grey based belly fur invariable in adults, conspicuously shortened skull and grooved upper incisors.

A raised nude presternal gland is seasonally developed in the male, but there is no tract of specialised hair on either gular or sternal sites. Pes comparatively stout, with large plump pads and the hallucal pad always present; under surface of toes very lightly haired. Ear long.

Pelage soft; mid-dorsally from 10-14 mm long; colour dorsally exceedingly variable, ranging from pinkish cinnamon of Ridgway scarcely pencilled with near black tips in the richer phases, through intermediate strongly grizzled drabs, to near blackish. Ventral fur white terminally and usually pale plumbeous at base, though white-based sub-adults occur.

Skull short and broad, with the anterior zygoma root strongly out-thrust and a square zygomatic outline. Interorbital space wide. Anteorbital fossa broad and shallow, with the external wall turned uniformly inward. Free margin of zygomatic plate with a shallow concavity only and with the upper spur little developed. Anterior palatal foramina usually exceeding the anterior margin of M¹ and very wide. Mesopterygoid fossa constantly wide and frequently lyrate in outline. Bulla small.

Upper incisors distinctly orthodont; narrow and delicate and with the anterior surfaces constantly marked by a broad and shallow groove.

*Dimensions.*—The range of flesh dimensions in 47 individuals and of skull dimensions in 17 is given in my paper of 1939 and Tate (1951) quotes some measurements of the lectotype.

*Type* (lectotype of Thomas, 1921).—British Museum No. 53, 10, 22, 7; collected by Capt. Charles Sturt in 1845 at 29°06′ S. lat. and 141° E. longt. Also recorded from Ooldea and several intermediate localities.

Ninety-three examples examined, many of them collected by L. Reese, Esq.

From 1929-34 this species appeared to be much more numerous in the Lake Eyre Basin than the next, but in recent collections the proportions have been reversed.

## 2. NOTOMYS FUSCUS Wood Jones, 1925

*Thylacomys cervinus* Waite, 1898, Proc. Roy. Soc. Vict., X, 2, 122; Pl. VI, Fig. 3 (in part)
    nec. *Hapalotis cervinus* Gould, 1853.
*Ascopharynx cervinus* Waite, 1900, Ann. Mag. Nat. Hist., 7 (5), p. 232 (in part); nec. *A.
cervinus* Waite, 1915, Trans. Roy. Soc. S. Aust., 39, p. 735 (= *N. alexis* Thos.).
*Ascopharynx cervinus* Wood Jones, 1925, Rec. S. Aust. Museum, III (1), p. 3 (in part)
*Ascopharynx fuscus* Wood Jones, 1925, *Ibid.*
*Notomys cervinus* Brazenor, 1934, Mems. Nat. Mus. Melbourne, 8, p. 82 (in part).
*Notomys cervinus* Finlayson, 1939, Trans. Roy. Soc. S. Aust., 63 (1), p. 108; Pl. IV, Figs.
    I, J and O; Pl. V, Figs. J, K and L.

A medium-sized species with a gular pouch in both sexes, strongly haired undersurface of toes and an elongate much modified skull, with tapered zygomatic outline.

The gular gland is constant and the floor of its pit is densely clothed with shining adpressed white hair, which forms a conspicuous disk in dried skins.

Rarely a sternal gorget of glandular hair is feebly developed in males. In the pes the undersurface of the toes is often thickly clothed with bristle hairs obscuring the integumental folds and overlapping the apical pads. The interdigital pads are relatively small and the hallucal pad may be absent. Ear very long.

The skull is differently shaped from that of *N. cervinus* Gould with a longer muzzle region, much less prominent anterior root of zygoma and a zygomatic outline which tapers markedly forwards. Interorbital region narrower. Anteorbital fossa narrow and deep and in fully adult examples the external plate often nearly parallel to the rostral axis. Free margin of zygomatic plate deeply concave and with a well-marked upper spur. The anterior palatal foramina variable in length, sometimes falling short of $M^1$ and relatively narrow. Mesopterygoid fossa somewhat variable and decidedly narrower than in *N. cervinus* Gould and the processes less frequently flared outwards at their extremities and often parallel. Bulla very large.

Upper incisors heavier than in *N. cervinus* Gould, less orthodont and their anterior surfaces ungrooved.

### Subspecies A. NOTOMYS FUSCUS FUSCUS Wood Jones, 1925
#### (as given by the author *op. cit. supra.*)

Pes relatively heavy; hallucal pad absent; rhinarium heavier and less hooked.

Pelage with dorsal colouration darker, isabelline brown or drab and with the bases of the ventral fur pale smoky.

*Type* (lectotype).—Young adult male in alcohol with skull removed and prepared. Formerly of the private collection of Professor F. Wood Jones, subsequently No. 524 in the museum of the Zoological Department of the University of Adelaide and now registered number M6258 of the South Australian Museum.

*Type Locality.*—Ooldea district, South Australia.

*Dimensions of the Type.*—Head and body, 105; tail, 127; pes, 34·5; ear, 25.

*Skull.*—Greatest length, 30·0; basal length, 24·5 ca.; zygomatic breadth, 15·2; brain case breadth, 14·4; interorbital breadth, 5·3; nasals, length, 10·7; nasals, breadth, 2·6; palatal length, 15·0; anterior palatal foramina, 4·9; bulla length, 5·8 ca.; upper molar series, 4·7.

### Subspecies B. Notomys fuscus eyreius nov.

Hallucal pad present in about 70 per cent. of the series examined. Pelage somewhat thinner and slightly crisper than in *N. cervinus* Gould of the same districts; the dorsal colour variable but generally brightly fulvous or rufescent; at its richest, orange cinnamon of Ridgway, more vinaceous than *N. cervinus* Gould and with light sepia pencilling rather than black, but in a large proportion of specimens scarcely different from the buff forms of that species. A dark ashy phase (about wood brown) occurs, with a frequency of less than 2 per cent. in the available sample. Ventral fur most frequently pure white to the base, but distinctly grey (pale plumbeous) in 10 per cent. of individuals.

*Type.*—Adult female; skin and skull; South Australian Museum, registered number M4595. Collected by G. Aiston, Esq., April, 1934.

*Type Locality.*—Mulka (New Well), on the east side of Lake Eyre about 50 miles ENE of the Barcoo inflow.

*Dimensions of the Type.*—Head and body, 100; tail, 141; pes, 35; ear, 25.

*Skull.*—Greatest length, 30·3; basal length, 24·8; zygomatic breadth, 16·2; braincase breadth, 15·3; interorbital breadth, 5·6; nasals, length, 10·9; nasals breadth, 2·8; palatal length, 15·1; anterior palatal foramina, 5·1; bulla length, 6·2 ca.; upper molar series, 5·0.

The range of flesh dimensions in 22 examples and of skull dimensions in four examples are given in my paper of 1939 (*supra*).

Fifty-two examples examined, including a series of 27 paratypes from Mulka and 25 from other localities in the Lake Eyre Basin, most of the latter having been collected and carefully prepared in the field by Mr. Paul Lawson of the Museum staff, and Mr. R. Tedford.

This species which occurs sympatrically with *N. cervinus* Gould and *N. mitchelli* vars. both in the Lake Eyre Basin and Ooldea district is readily distinguishable from them by both somatic and cranial features. From *N. alexis* Thomas which is now known to occur on the north-east margin of the Basin, the distinction is equally valid, though sometimes less obvious, and is more justly appreciated in series than individually.

The chief points in which *N. alexis* differs are as follows. Both foot and ear are smaller; the ear decidedly so, both length and breadth averaging lower and the overall size therefore markedly less. The dorsal pelage shows a range of ferruginous brown tones in the subterminal band quite absent from *N. fuscus*. White-based belly fur occurs in *N. alexis*, though with much less frequency than in *N. fuscus eyreius*; but distinction from *N. fuscus fuscus* in this character may not be practicable. The gular pit is less strongly haired, and in dried material its site is marked by an oval area of nude skin rather than a disk of specialised hair. On the other hand, the sternal tract of glandular hairs in males is strongly developed and resembles the condition in *N. mitchelli*.

The adult skull is generally less modified in outline and more *pseudomys*-like than in *N. fuscus*, though examples occur which are difficult to distinguish and in the remaining points listed the distinction is also of an average character. The brain case is smaller, narrower and less pyriform; the zygomatic process of maxilla in lateral aspect less expanded and differently shaped; the anteorbital fossa broader and shallower; the anterior palatal foramina wider; the bulla decidedly smaller and the incisors more opisthodont.

## ACKNOWLEDGMENTS

# THE RELATIONSHIP BETWEEN ILLUMINATION AND GLOBAL RADIATION

BY *J. N. BLACK*

## Summary

An examination has been made of the relationship between illumination and global radiation for five stations for which long term records of both factors are available (Helsinki, Stockholm, Kew, Vienna and Jerusalem), to determine whether radiation data can be used as an index of the light climate in studies of agronomy and plant ecology. Despite differences in instrumentation and climate there was found to be a high correlation between illumination and radiation and there is no significant departure of the data for any individual station from the common regression. It is concluded that, at least for the climates of which the six stations are representative, radiation can be used with confidence as an index of the light climate.

# THE RELATIONSHIP BETWEEN ILLUMINATION AND GLOBAL RADIATION

## By J. N. Black[*]

## [Read 13 August 1959]

## SUMMARY

An examination has been made of the relationship between illumination and global radiation for five stations for which long term records of both factors are available (Helsinki, Stockholm, Kew, Vienna and Jerusalem), to determine whether radiation data can be used as an index of the light climate in studies of agronomy and plant ecology. Despite differences in instrumentation and climate there was found to be a high correlation between illumination and radiation and there is no significant departure of the data for any individual station from the common regression. It is concluded that, at least for the climates of which the six stations are representative, radiation can be used with confidence as an index of the light climate.

In the study of agronomy and plant ecology there frequently arises a need for data on the average illumination to which plants are exposed, for instance when the growth or geographical distribution of field crops or pastures are under consideration. Recent studies in the relationship of leaf area and incoming light energy (e.g. Brougham, 1957; Donald and Black, 1958; and Black, 1958), which have led to a better appreciation of the basic principles involved in the growth of pastures, have drawn attention to the limited understanding of the spatial distribution of illumination. Unfortunately, the number of stations for which long term records of light energy are available is very small, and in the absence of such records, recourse has often been made in the past to some general relationship between light intensity and global radiation such as that put forward by Kimball (1924) (e.g. Black, 1957; Brougham, 1958), or to the values given by Moon (1940) for the distribution of energy between various wavelength bands of the incoming solar radiation (Tamiya, 1957; Blackman and Black, 1959). Both Kimball's and Moon's values vary, as would be expected, with atmospheric conditions; Kimball quotes a range of values for different cloud cover while Moon's are calculated for a number of optical air masses.

Since it has not been possible to study the distribution of illumination directly from measured values, interest has been concentrated on the distribution of radiation; a study by Black, Bonython and Prescott (1954) of the relationship between radiation and sunshine could not be extended to the charting of radiation since the distribution of sunshine was itself unknown, except in the broadest terms. A further attempt was made by Black (1956) to relate radiation to mean cloud amount, and this was followed by the preparation of monthly maps of the distribution of incoming global radiation. It appears that two other studies were proceeding simultaneously with similar objects: Budyko (1955) was interested in radiation balance, but his "Atlas of Heat Balance" includes maps of global radiation, and a more recent study has been published by Bernhardt and Philipps (1958). It is therefore of considerable interest to ascertain to what extent the use of maps of radiation to obtain an estimate of illumination climate is justified. Blackwell (1954), examining the

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TABLE 1

Stations for which data are available

| Place | Latitude | Longitude | Length of records | Instrument | | Source of data |
|---|---|---|---|---|---|---|
| | | | | Radiation | Illumination | |
| Helsinki | 60·2N | 25·0E | 5 years, 1929-33 | Ångström | Potassium photocell | Lunelund 1936 |
| Stocksund | 59·4N | 18·1E | 10 years, 1928-37 | Ångström | Potassium photocell | (1) Aurén 1933<br>(2) Aurén 1939<br>(3) Sveriges Meteorologiska och Hydroliska Institut. Årsböker |
| Kew | 51·5N | 0·3W | 5 years, 1947-51 | Moll-Gorczynski | Kew Recording photometer | (1) Blackwell 1953<br>(2) Blackwell 1954 |
| Vienna | 46·7N | 16·4E | 11 years, 1946-56 | (1) Robitzsch<br>(2) Stern | Selenium photocell | (1) Zentralanstalt für Meteorologie und Geodynamik Jahrbücher<br>(2) Sauberer 1958 |
| Jerusalem | 31·8N | 35·3E | 2 years, 1954-6 | Eppley | Lange Selenphotometer | Ashbel 1956 |

series of records of illumination and global radiation maintained at Kew between 1947 and 1951, pointed out that from the mean monthly values of luminous efficiency obtained from these records it would be possible to deduce approximate illumination values where only radiation data were available, and that these values would hold regardless of cloud amount. Blackwell further observed that his results were somewhat tentative and were only relevant to the five-year period under observation, to the methods of measurement and to the local conditions of exposure and climate.

More recently, a detailed study of the illumination climate of Pretoria, South Africa, has been published by Drummond (1958), which includes a comparison of the luminous efficiency of daylight for various locations. Drummond discussed in particular the values of luminous efficiency on clear days, and its relationship to atmospheric moisture content and turbidity, and showed that for four selected months (March, June, September and December) there were differences in luminous efficiency between the various stations examined.

It was felt that a suitable approach to the problem would be to assemble, for as many locations as available, data of radiation and illumination for average conditions of cloudiness, using mean values for each month over as long as possible periods of years. A list of stations for which suitable records are available, with the appropriate literature references, is given in Table 1. It will be seen that they are all located in Europe or the eastern Mediterranean, and that no records are available for tropical conditions. Unfortunately, Drummond (1958) did not publish illumination values for average cloud conditions, and his data for Pretoria cannot be used in the present study. It is probable that other records exist but are not known to the author; for instance, Lopukin (1953) has published illumination values for Tashkent, but it has not been possible to obtain appropriate global radiation data. There are, moreover, a number of limitations which must be borne in mind when data from these various stations are being examined. Firstly, different instruments have been used at the different stations; this is perhaps of more consequence in the illumination than in the radiation measurements, but it has not proved possible to introduce any correction factor. Secondly, the data for the various stations are for different years. This is unlikely to be of importance, since it is reasonable to assume that the relationship between illumination and radiation will not vary between years, and the data for each individual station were obtained simultaneously. Thirdly, the illumination data for Jerusalem were not obtained by continuous recording but by instantaneous hourly readings on clear days only. (Ashbel, personal communication.) Since there are practically no clouds during the summer at Jerusalem, Ashbel considers that the data for the months May to October may be accepted as representative for the whole month, whereas the values for the winter months must be discarded. In view of the marked difference between the climates of Jerusalem and the other stations, it is unfortunate that the data are limited not only in this way, but also in having been taken only for a very short time. Two small points may also be noted: firstly the illumination values for Helsinki and Stocksund (a suburb of Stockholm) were published in EsH units, and have been converted for the purpose of this study into Kilolux-hours by the factor 1 Es = 77,000 lux given by Pohjakallio (1952). Secondly, the illumination data for Kew have been amended in accordance with the suggestion of Blackwell, Eldridge and Robinson (1954).

The mean monthly values of illumination and global radiation calculated from the available data are given in Figure 1. It will be seen that despite the differences in instrumentation, geographical location, time of year and length of record, the data show little scatter and are, in fact, remarkably consistent.

There is, in fact, no significant departures of individual stations from the common regression, and any effect of varying cloud cover on the relationship between illumination and radiation has disappeared in the use of long term average data. It may therefore be concluded that the use of radiation data,
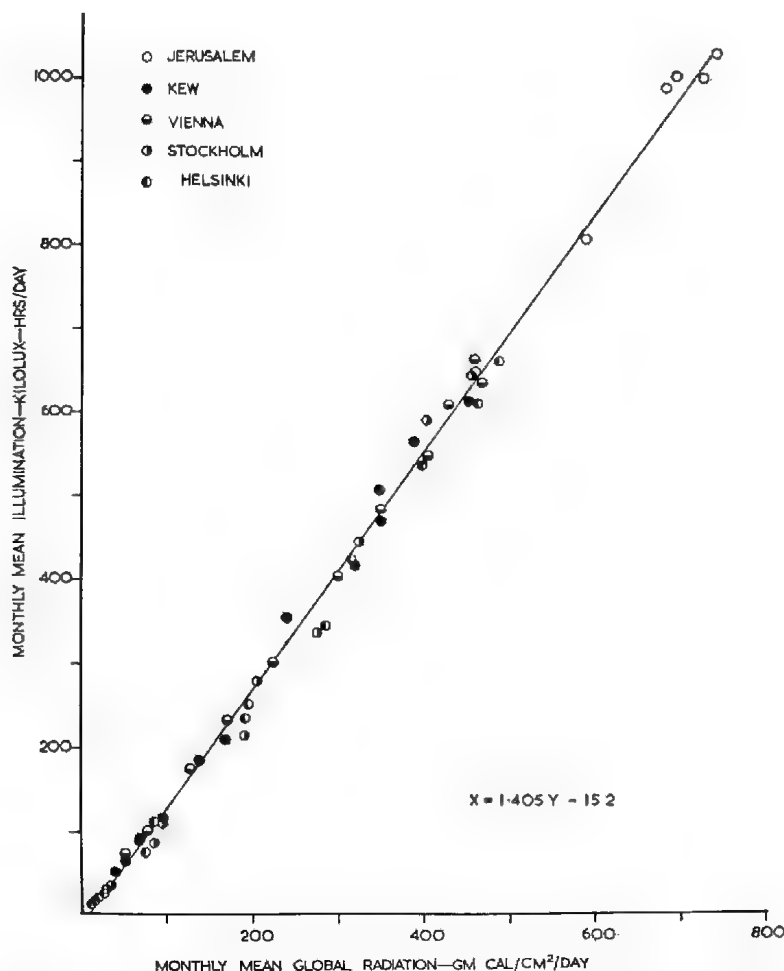


Fig. 1.—The relationship between illumination and global radiation.

either directly, as indicative of light energy, or by the use of a suitable conversion factor, is a satisfactory method of estimating light climate where no illumination data exist. It must, however, be stressed that the extension of this relationship to other climates—e.g. tropical or sub-tropical—which are not represented in the stations examined, will not be justified until confirmed by further data.

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# SOME AUSTRALIAN ECHIUROIDS (ECHIUROIDEA)

*BY* S. J. *EDMONDS*

## Summary

Four new species of echiuroids, Thalassema sydniense, Arhynchite hiscocki, Anelassorhynchus adelaidensis and Ochetostoma autraliense are described and six other species are listed from Australia. Some anatomical details of Pseudobonellia biuterina Johnston and Tiegs are redescribed and a key to the genera of Australian echiuroids is given.

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## By S. J. Edmonds[*]

### [Read 10 September 1959]

## SUMMARY

Four new species of echiuroids, *Thalassema sydniense*, *Arhynchite hiscocki*, *Anelassorhynchus adelaidensis* and *Ochetostoma australiense* are described and six other species are listed from Australia. Some anatomical details of *Pseudobonellia biuterina* Johnston and Tiegs are redescribed and a key to the genera of Australian echiuroids is given.

## I. INTRODUCTION

The phylum Echiuroidea consists of a group of unsegmented, coelomate, marine invertebrates that is closely related to the Annelida and the Sipunculoidea. The phylum contains two chief families, the Echiuridae and the Bonellidae.

The present paper describes four new species and refers to the species previously recorded from Australia. Some anatomical details of one of the latter are re-described. The scheme of classification used is that adopted by Fisher (1946, 1948). The species are:

### Family ECHIURIDAE

1. *Thalassema sydniense* n. sp.
2. *Arhynchite hiscocki* n. sp.
3. *Anelassorhynchus vegrandis* (Lampert).
4. *Anelassorhynchus porcellus* Fisher.
5. *Anelassorhynchus adelaidensis* n. sp.
6. *Ochetostoma australiense* n. sp.

### Family BONELLIDAE

7. *Bonellia haswelli* Johnston and Tiegs.
8. *Pseudobonellia biuterina* Johnston and Tiegs.
9. *Archibonellia michaelseni* Fischer.
10. *Archibonellia mjobergi* Fischer.

## II. DESCRIPTION OF SPECIES

### 1. Thalassema sydniense n. sp.

pl. 1a, figs. 1-2

*Thalassema* Lamarck, 1801: Fisher, 1946, p. 230.

*Specimens*—4 (2 dissected): Aust. Museum specimens G11219.

*Locality*—Off Watson's Bay, Port Jackson, N.S.W.

*Description*—The four specimens are small and in the preserved state grey-brown in colour. The length of the trunk is 6-12 mm. and the maximum width 2-5 mm. The proboscis, still attached to the trunk in all specimens, is about half to a third as long as the trunk and gradually narrows anteriorly. The sur-

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face of the animal is covered with numerous, very small, rather flat papillae which appear to lie almost in transverse rows. They are more noticeable at the anterior and posterior regions of the trunk. The longitudinal musculature of the body wall is continuous.

Only a limited amount of information about the internal anatomy was obtained from the dissected specimens. The setae are comparatively large and prominent and strongly recurved at the tip. They are connected by a very prominent interbasal muscle. Another well-developed muscle runs from the base of each seta to a point on the body wall posterior to the nephridiopore of the first pair of nephridia. There are two pairs of nephridia all of which open to the exterior posteriorly to the point of extrusion of the setae. The lips of the nephrostomes are not elongated or spirally coiled and the internal opening is on a short peduncle near the base of the nephridia.

No satisfactory information can be given about the alimentary and vascular systems. The anal vesicles are about half as long as the trunk. No pre-cloacal, intestinal caecum appears to be present, but this point should be checked when more specimens are available for examination.

*Systematic Position.*

This species resembles *Thalassema steinbecki* Fisher, 1946, which is found along the Pacific coast of America from California to Ecuador. It differs, however, from *T. steinbecki* because the nephrostomes are on short expanded peduncles and for this reason it is considered to be a new species.

*T. sydniense* is known only from four specimens all of which are small. It differs from *A. porcellus* and *A. adelaidensis* in that:

(1) the lips of its nephrostomes are not spirally coiled;

(2) a strong interbasal muscle joins its setae;

(3) the nephridiopores of the first pair of nephridia lie between the setae and the point of fixation on the body wall of a well-developed, posteriorly directed, setal muscle.

*Type Locality*—Off Watson's Bay, Port Jackson, N.S.W.

*Type Specimen*—Australian Museum, Sydney.

## 2. Arhynchite hiscocki n. sp.

pl. Ib, fig. 3

*Arhynchite* Sato, 1937, p. 142; Fisher, 1949, p. 485.

*Specimen*—1 (collected by Dr. I. Hiscock, University of Queensland).

*Locality*—"Dug from sand 18 in. down on the sandspit", Dunwich, Queensland.

*Description*—The specimen is long, slender and pencil-like. The length of the trunk is about 10 cm. and its width 4-6 mm. The specimen, preserved in alcohol, is yellow in colour. The body is covered with small, uniformly distributed papillae which are slightly larger at its anterior and posterior extremities. The papillae give the impression of being arranged in transverse rows. Anteriorly there is a very delicate and slender proboscis about 3 cm. long and 1-2 mm. wide. It is still attached to the trunk and its anterior extremity is flattened so as to make it fan-like. The longitudinal musculature is continuous and not grouped into bundles.

The specimen possesses one pair of nephridia about 1·5 cm. long that open to the exterior behind the setae. Each of the nephridia possesses a rather elaborate, leaf-like nephrostomal lip. The setae are long and are connected to strong, radiating muscles which arise from the body-wall. There is a well-developed interbasal muscle. The alimentary canal is very long and considerably coiled. The oesophagus if firmly fastened to the body by well-developed

SOME AUSTRALIAN ECHIUROIDS (ECHIUROIDEA)

mesenterics and the presiphonal segment is very long.  No precloacal caecum is present on the intestine.

The vascular system consists of a prominent, tubular dorsal vessel that is closely associated with the alimentary canal for a considerable part of its length. It then appears to fuse with the intestine.  The ventral vessel gives off a branch that joins the intestine at a point posterior to the point of fixation of the dorsal vessel.  There does not appear to be a ring vessel.  The system resembles rather closely that of a bonellid.

There are two very thin, slightly brown anal vesicles, the length of which is about one-quarter that of the trunk.  On their surface there are numerous very small structures, presumably the ciliate funnels, that are visible only with the aid of a magnifier.  The anal vesicles are fastened throughout their whole length by numerous fine muscles to the posterior region of the alimentary canal, but to the body wall only over the last quarter of their length.

*Systematic Position.*

This species differs from other species of the genus in (1) the structure of its vascular system, and (2) the way that the anal vesicles are attached principally to the alimentary canal and not to the body.  The most closely related species is A. *arhynchite* (Ikeda) described from Japan.

The genus *Arhynchite* as defined by Sato (1937, p. 142) contained echiurids which did not possess a proboscis.  Fisher (1949, p. 485), after finding two species that possessed a long deciduous proboscis, re-described the genus.  The proboscis of the Australian species described in this paper was still attached to the specimen when it was collected.

A. *hiscocki* differs from other Australian echiurids in that:
(1) its proboscis is very slender and flattened anteriorly; and
(2) the lips of the nephrostomes are expanded into elaborate, leaf-like structures.

*Type Locality*—Dunwich (Stradbroke Is.), Queensland.

*Type Specimen*—Australian Museum, Sydney.

### 3. Anelassorhynchus vegrandis (Lampert)

*Thalassema vegrande* Lampert, 1883, p. 341.
*Anelassorhynchus vegrandis* Fisher, 1949, p. 481.

*Australian Record*—Low Is., Great Barrier Reef, Queensland (Monro, 1931).

*Remarks*—Monro gives no details of the anatomy of his specimens.  A. *vegrandis* possesses three pairs of nephridia, all of which open to the exterior posteriorly to the setae.  The lips of the nephrostomes are coiled.

### 4. Anelassorhynchus porcellus Fisher

pl. 1c

*Anelassorhynchus porcellus* Fisher, 1948, p. 274.

*Specimens*—12 (6 dissected).  Collected by the author from under pieces of coral rock lying in loose coral sand near the level of low spring tides: 19/8/55.

*Locality*—Heron Is (Capricorn Group), Queensland.

*Description*—The animals are plump and sac-like and when alive sandy-grey in colour.  The length of the trunk is 2·5-4·0 cm. and the maximum width 1·5-2·3 cm.  The proboscis is 1·2-1·8 cm. long and readily deciduate; it tapers slightly anteriorly.  The body wall is wrinkled and made verrucose by the presence of numerous flat papillae, which are largest on the anterior and posterior surfaces of the trunk.  The skin appears to be thinner and smoother on the dorsal than the ventral surface.  The musculature is continuous and not

grouped into bundles and two rather inconspicuous golden-coloured setae lie just posterior to the mouth. No interbasal muscle was found connecting them.

The alimentary canal is very long and frail. In all specimens it was filled with fragments of coral, small shells and coral sand which had ruptured the thin wall in many places. This prevented a thorough examination of the alimentary canal being made. The presiphonal section, however, is very long. The dorsal blood vessel is attached only to the anterior-most part of the foregut. There is a ring vessel, two dorso-ventral vessels which unite at a level just posterior to the setae and eventually connect with a rather poorly developed ventral vessel. There are two pairs of nephridia which open posteriorly to the setae. Their nephrostomes bear long, slender and slightly coiled prolongations which are often entangled in the coils of the intestine. The nephridia vary in size and in shape; in most specimens they are slender. There are two long, anal vesicles with numerous small unstalked funnels which appear to be in longitudinal rows. No caecum was found in the intestine.

*Systematic Position.*

I have not been able to find any character which can be used to distinguish these specimens from A. *porcellus*, Fisher described from Hawaii, where it has been found in sand under rocks in tide pools. The lips of the nephrostomes of the specimens from Queensland are less coiled and the ventral blood vessel appears to be not as well developed as those of A. *porcellus*. These differences may be caused by different methods of fixation.

A. *porcellus* possesses two pairs of nephridia which open behind the setae and which possess long spirally coiled lips. The presiphonal of the gut is very long.

*Distribution*—Hawaii; Heron Is., Queensland.

## 5. Anelassorhynchus adelaidensis n. sp.

pl. 2a

*Anelassorhynchus* Annandale, 1922, p. 148.

*Specimens*—8 (5 dissected).

*Localities*—St. Vincent Gulf, South Australia. Seven specimens were collected by the author from the sand and gravel amongst the roots of the marine angiosperm, *Cymodocea antarctica* at Aldinga Beach and one at Cape Jervis by Mrs. P. M. Thomas.

*Description*—This species is closely allied to A. *porcellus* Fisher, described from Hawaii and reported in the present paper, from Heron Is., Queensland. The South Australian specimens when alive are rich dark green in colour, while those from Queensland are sandy-grey. The length of the trunk of the specimens is 6-10 cm. and the maximum width 1·5-3·0 cm. The proboscis, a deciduous structure, is 2-4 cm. long and 0·5 cm. wide and tapers anteriorly. Its margin, though slightly wavy, is not frilled and its groove or trough is light green in colour. The skin of the animal is wrinkled and bears numerous small, flat, glandular papillae. The maximum length of the setae is 5 mm. and there is no interbasal muscle. The longitudinal musculature of the body-wall is continuous.

There are four nephridia which open behind the setae and which possess spirally coiled and elongate lips. The alimentary canal is long and tangled. Its presiphonal section is very long (as much as 8 cm. in one specimen) and thin-walled. There is no precloacal caecum.

The blood vascular system consists of a dorsal blood vessel, a ring vessel and two dorso-ventral vessels which join the ventral vessel. The latter is closely pressed to the ventral nerve cord. There are two long and slender anal vesicles which are attached to the body-wall only posteriorly. The vesicles are brown

in colour and their surface is covered with numerous, minute, brown funnels. The diameter of eggs found in the nephridia of one female was 0·13-0·17 mm. Whether they were ripe could not be ascertained.

*Systematic Position.*

These specimens resemble two specimens of a dark green echiurid collected at Amboina and described by Fischer (1896) as *Thalassema semoni.* *A. semoni* possesses four nephridia with spirally coiled lips. In one of Fischer's specimens all the nephridia open to the exterior behind the setae but in the other the first pair do not. Wharton (1913, p. 247) re-described the species from Buquet Is. (Philippines). According to him the first pair of nephridia open in front of and the second pair behind the setae. Since both pairs of nephridia of the South Australian specimens open behind the setae, it is most likely that they are a different species from *A. semoni.*

*A. adelaidensis* possesses two pairs of nephridia which open behind the setae and which have long, spirally coiled, nephrostomal lips. The presiphonal section of the gut is long. It is dark green in colour, differing in this respect from *A. porcellus* Fisher.

*Type Locality*—Aldinga Beach (near Adelaide), St. Vincent Gulf, S.A.

*Type Specimen*—Australian Museum, Sydney.

### 6. Ochetostoma australiense n. sp.

pl. 2b, fig. 4

*Ochetostoma* Leuckart and Ruppell, 1828; Fisher, 1946, p. 240.

*Specimens*—21 (12 dissected).

*Localities*—Queensland: Stradbroke Is. (3 three specimens coll. S. Hynd), Myora (two specimens coll. I. Hiscock), Dunwich (eight specimens coll. I. Hiscock), Palm Is. (two specimens, from Univ. of Queensland). New South Wales: Goodwood Is., near mouth of Clarence River (six specimens coll. P. Durie). Aust. Museum specimens W3375, W3186, W3187.

*Description*—Mr. P. Durie says that the worms from Goodwood Is. are found "between high and low water marks in rather dark sand, situated close to some small mangrove clumps. The proboscis is white and fleshy and protrudes from a hole in the sand. It lies along the surface of the sand and is about 6 in. long and ½ in. wide. In this condition it appears to be quite flat (like a ribbon) and does not appear to take on a tube-like shape as in preserved specimens. The body of the worm is soft and bright red in colour. Twelve longitudinal muscle bundles show up very clearly."

The length of the trunk of preserved specimens is 4·3-10·2 cm. and the maximum width 1·8-2·8 cm. The proboscis is 1·8-4·1 cm. long and not readily deciduate. Living specimens are red but preserved specimens are pale pink or straw coloured. The thickness of the skin varies. In some specimens it is thick, in others thin, the condition probably depending on the state of the musculature at fixation. There are usually 12-13, occasionally 11-14, longitudinal muscles which are best counted in dissected specimens. In all specimens except two there was one more band in the posterior half than the anterior half of the trunk. Of the 12 dissected specimens the maximum number of bands was 14 in one specimen, 13 in five, and 12 in six. The oblique musculature between the longitudinal bundles is grouped into numerous fascicles. The fascicles are not always noticeable in those parts of the body which have been stretched considerably. The anterior and posterior surfaces of the trunk bear small flat papillae.

There are three pairs of nephridia which vary in size and shape; generally they are long. One pair opens anteriorly to and the other two pairs posteriorly
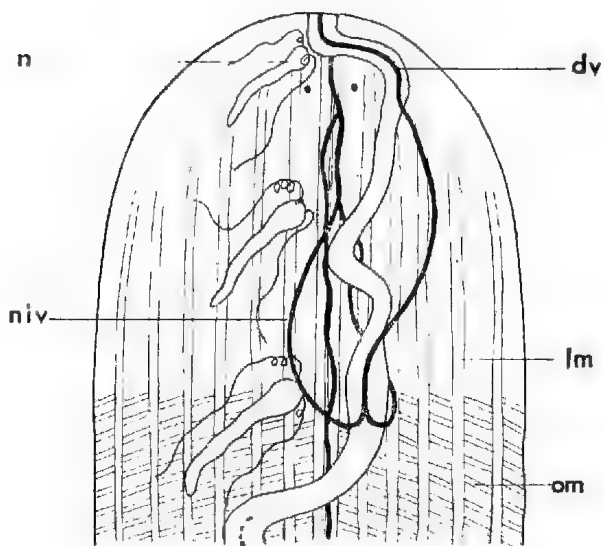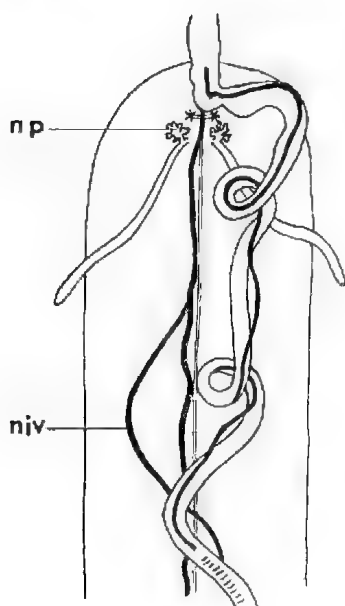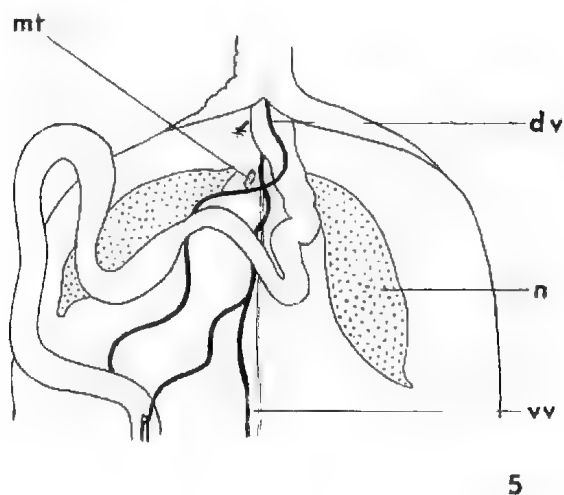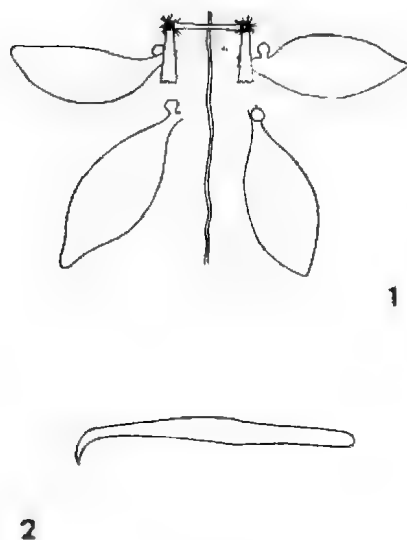
Figs. 1-2.—*Thalassema sydniense*; 1, anterior region dissected to show nephridia, setae and setal muscles; 2, seta.

Fig. 3.—*Arhynchite hiscocki*; dissected specimen.

Fig. 4.—*Ochetostoma australiense*; dissected specimen showing anterior region of body.

Fig. 5.—*Pseudobonellia biuterina*; dissected specimen showing anterior region of body.

Legend.—dv = dorsal vessel, lm = longitudinal muscle, mt = male tube, n = nephridium, niv = neuro-intestinal vessel, np = nephridial process, om = oblique muscle, vv = ventral vessel.

to the setae. All the nephrostomes have long spirally coiled lips. No interbasal muscle was found between the setae. The alimentary system consists of a short anterior region, a long intestinal region possessing a ciliate groove and siphon and a short rectum. The anterior region is held in position by strong mesenteries attached to the body-wall and the other regions by numerous fine filaments. There is a precloacal, intestinal caecum.

The blood system is similar to that found in a number of species of *Oche-tostoma*, e.g. *O. octomyotum* Fisher, 1946. There is a dorsal vessel, a ring vessel, two dorso-ventral vessels and a ventral vessel. The latter is placed close to the nerve cord and connects posteriorly with the precloacal caecum. There are two long anal vesicles with small unstalked ciliate funnels.

*Systematic Position.*

At least six species of *Ochetostoma* have been described that possess three pairs of nephridia, one pair of which opens in front of and two pairs behind the setae: *O. erythrogrammon* Leuckart and Ruppell, 1828, *O. stuhlmanni* (Fischer, 1892), *O. leptodermon* (Fischer, 1892), *O. caudex* (Lampert, 1883), *O. kokotoniense* (Fischer, 1892) and *O. griffini* (Wharton, 1913). Sato (1939, p. 357) considers the first five of these species to be synonymous.

The specimens from Australia are very close to *O. erythrogrammon* described from the Red Sea by Leuckart and Ruppell (1828). According to Fischer (1927, p. 112) the original description (which was not available to the present author) is "nur oberflächlich". Fischer (1927, p. 115) re-examined the species and described it as possessing 14-18 longitudinal muscle banners. This last point has been re-confirmed recently by Wesenberg-Lund (1957, p. 9) who re-examined a number of species of *O. erythrogrammon* from the Red Sea. She says, "There are 17 longitudinal muscles but at the level of the hooks the two dorsal-most bands on each side unite so that there are only 15 bands in the anterior part of the trunk".

There seems little doubt, therefore, that the species from the Red Sea possesses 14-18 bands, whereas that from eastern Australia possesses 11-14, usually 12-13. For this reason the latter is regarded as new and described as *O. australiense*.

*O. australiense* is a rather large species in which the longitudinal musculature of the body-wall is divided into 12-13, occasionally 11-14, bundles. It possesses three pairs of nephridia, the first pair of which opens in front of and the other two pairs behind the setae. Its anatomy resembles that of *O. erythrogrammon*.

*Type Locality*—Dunwich (Stradbroke Is.), Queensland.
*Type Specimen*—Australian Museum, Sydney.


### 7. Bonellia haswelli Johnston and Tiegs

*Bonellia haswelli* Johnston and Tiegs, 1920, p. 73.
*Bonellia viridis* Whitelegge, 1889.

*Australian Record*—Port Jackson, N.S.W. (Johnston and Tiegs, 1920).

*Remarks*—This species is known only from the account of Johnston and Tiegs (1920). The length of the trunk is over 2 in. and the maximum breadth ¾ in.; the length of the contracted proboscis 4 in. and of each of its arms 1½ in. A siphon, about ½ in. long, originates as a very narrow tube on the dorsal surface of the pharynx, widens posteriorly and ends blindly in a lobed structure. A single nephridium about ½ in. long is situated on the left side of the body. The nephrostome is situated about a quarter of the length of the nephridium from its free end. The ovary is mid-ventral along the nerve cord. There are two

anal vesicles into which open about 15 tubes from which are given off smaller tubes with ciliate funnels. Coloured green when alive; the male is unknown.

This species possesses only one nephridium and consequently can be readily distinguished from *Pseudobonellia biuterina*, *Archibonellia michaelseni* and *A. mjobergi* which possess 2-3 nephridia.

### 8. Pseudobonellia biuterina Johnston and Tiegs

pl. 2c, fig. 5

*Pseudobonellia biuterina* Johnston and Tiegs, 1919, p. 213; Fisher, 1946, p. 249.

*Specimens and Localities*—49 (12 dissected).

Queensland: North West Is. (5) (University of Queensland), Arkhurst and Hayman Is. (2) (coll. Dr. Mackerras), Whitsunday Passage (2) (Aust. Mus. Coll., W3029), Heron Is. (2) (coll. S. J. Edmonds).

Western Australia: Fremantle Harbour (21) (Mrs. L. Marsh), Dongarra (6) (coll. Prof. A. G. Nicholls), Pt. Peron (2) (coll. Prof. T. H. Johnston), Trigg Is. (8) (coll. M. J. Littlejohn).

*Previous Australian Record*—North West Islet, Masthead Is. (Capricorn Group), Queensland (Johnston and Tiegs, 1919).

*Description and Discussion*—The specimens from Queensland, although they differ in a few respects from Johnston and Tiegs's description of the species, are considered to be *P. biuterina*. Five specimens were collected at one of the type localities and two others at an adjacent island. They possess two nephridia (uteri) and carry a degenerate male in a small blind tube which opens to the exterior between the two nephridiopores. The male aperture shows up clearly just below the setae in all species.

The vascular system of the specimens is much more like that of a typical bonellid (Fisher, 1946, Fig. 15) than that described by Johnston and Tiegs. There is a dorsal vessel which makes contact with the alimentary canal at three points: anteriorly with the pharynx, then (usually) at a point on the oesophageal wall near the crop and finally at a point where it fuses with the intestinal wall just anterior to the origin of the siphon. A ventral or neural vessel runs along the nerve cord to the posterior region of the animal. Anteriorly, the ventral vessel gives off a neuro-intestinal vessel which makes contact with the intestine near the anterior extremity of the siphon. The neuro-intestinal vessel runs along the intestine and is closely associated with the siphon for about 1·5 cm. (Fig. 5).

The anal vesicles do not seem to communicate with the cloaca as simply as described by Johnston and Tiegs. The ciliate tubules arise in groups or fascicles from a slight outpocketing of the cloacal wall and show in some specimens some branching basally.

Johnston and Tiegs state that the ovaries "lie transversally on frenulae". The ovaries were inactive and invisible in the dissected specimens from North West Is. but in the specimens from Arkhurst and Hayman Is. developing ova, although small, lie clearly longitudinally along the posterior third of the ventral nerve cord. The transverse position of the ovaries, therefore, must be regarded with reserve until more specimens with gonads are available for study.

The vascular system and the anal vesicles of the Western Australian specimens are like those of the Queensland specimens. The ovaries of six specimens lie along the nerve cord. Eggs with a diameter of 0·25-0·3 mm. were found in the nephridia of the W.A. specimens. About 15 nematodes were obtained from the intestine of two specimens from Fremantle. They were found in the mid-gut and showed no sign of attrition or digestion. Whether they were

ingested along the sand and debris or whether they are intestinal parasites is not known.

*Systematic Position.*

P. *biuterina* is dark green in colour. It possesses two nephridia and a small blind tube which opens to the exterior between the nephridiopores. The male is carried in the tube. *P. biuterina* differs from A. *michaelseni* Fischer, also described from Fremantle, W.A., in that its intestine is long and lacks a caecum and in the structure of the anal vesicles.

### 9. Archibonellia michaelseni Fischer

*Archibonellia michaelseni* Fischer, 1919, p. 83; 1921, p. 7.

*Australian Record*—Fremantle and Rottnest Is., Western Australia (Fischer, 1919).

*Remarks*—This species is described from a single specimen. The trunk of the specimen is about 12 mm. long and the proboscis terminates in two short lappets. The colour of the animal when alive is grey. The species possesses two very small nephridia and an unpaired "uterus". The intestine is short and bears a small caecum. The ovary lies along the posterior region of the nerve cord. The anal vesicles terminate in a bundle of tubules.

### 10. Archibonellia mjobergi Fischer

*Archibonellia mjobergi* Fischer, 1921, p. 6.

*Australian Record*—Broome, Western Australia (Fischer, 1921).

*Remarks*—This species is also described from a single "coal black" specimen. The trunk is 45 mm. long and the proboscis 18 mm. One arm of the proboscis is 50 mm. long and the other 10 mm. The species possesses one pair of large nephridia between which lies a very small unpaired nephridium.

## III. KEY TO THE GENERA OF AUSTRALIAN ECHIUROIDS

1. Proboscis usually conspicuous (although sometimes deciduous if specimen is handled) and often several times the length of the body but never bifid. Anal vesicles long, sac-like, unbranched and covered with minute ciliate funnels — family *Echiuridae* .. ... ... ... .... 3, 4

2. Females with elongate, bifid proboscis. Anal vesicles with many branches that end in ciliate cups. Male degenerate, living in or on the female — family *Bonellidae* ⁅.. ... ... .... .. . .... 9, 10

3. Longitudinal muscles of body-wall grouped into bundles. The interval between the bundles is crossed by numerous separate, small bundles of the inner oblique layer. 1-4 pairs of nephridia with spirally coiled, nephrostomal lips — genus *Ochetostoma.*

4. Longitudinal muscles of body-wall not grouped into bundles 5, 6

5. Nephrostomal lips either coiled or expanded into leaf-like structures 7, 8

6. Nephrostomal lips neither coiled nor expanded into leaf-like structures — genus *Thalassema.*

7. Nephrostomal lips long and spirally coiled — genus *Anelassorhynchus.*

8. Single pair of nephridia with nephrostomal lips produced to form leaf like structures. Proboscis long, deciduous and slender with a small fan like extremity — genus *Arhynchite.*

9.    Only one nephridium or uterus present.  Coelomic aperture of the nephri-
      dium is situated near the base of nephridium at the end of a short lateral
      tube — genus *Bonellia*.

10.   More than one nephridium or uterus      .....    .....    ...    ...    11, 12

11.   Two nephridia or uteri with nephrostomes placed near their distal ends.
      male permanently lodged in a small blind tube which opens between the
      nephridiopores — genus *Pseudobonellia*.

12.   Third nephridium placed between two paired nephridia — genus *Archi-
      bonellia*.


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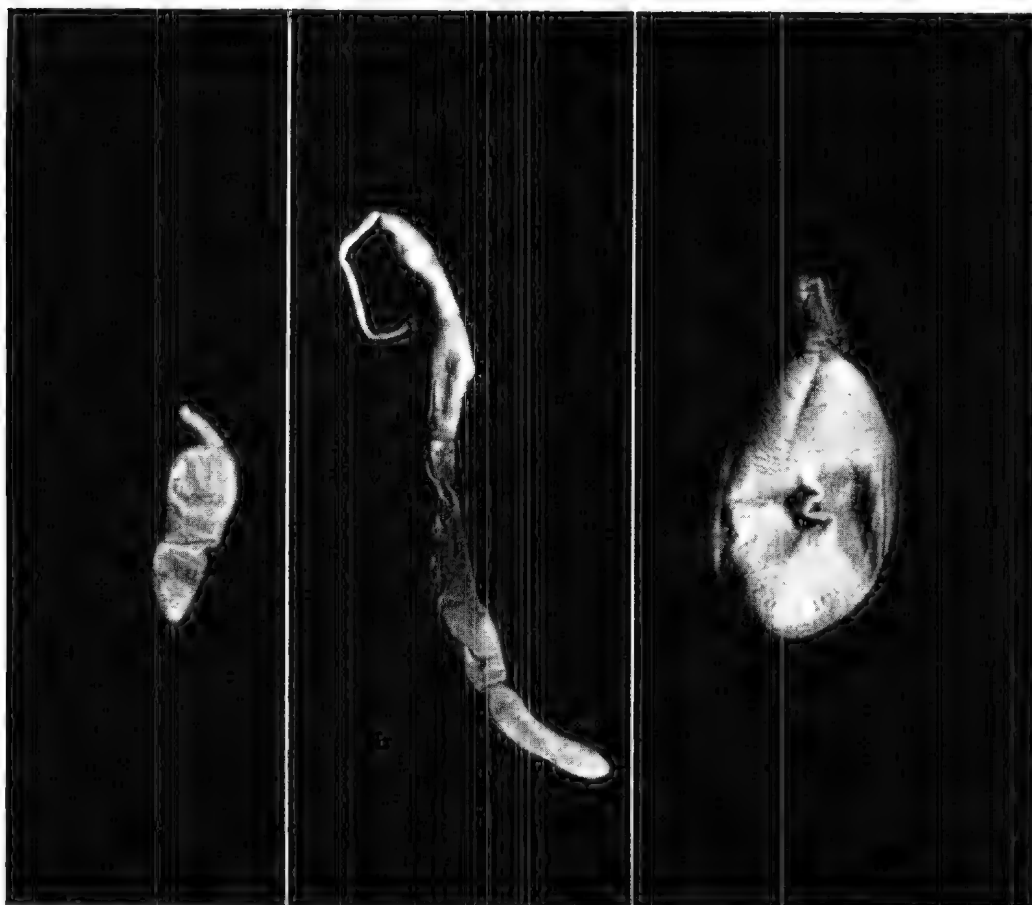
*Thalassema sydniense*
1a.—This figure is twice natural size.

*Arhynchite hiscocki*
1b.—This figure is 8/10 natural size.

*Anelassorhynchus porcellus*
1c.—Natural size.

*Anelassorhynchus
adelaidensis*
2a.—Natural size.

*Ochetostoma
australiense*
2b.—2/3 natural size.

*Pseudobonellia
biuterina*
2c.—1·5 × natural
size.

# THE SAND RIDGE DESERTS OF SOUTH AUSTRALIA AND RELATED AEOLIAN LANDFORMS OF THE QUATERNARY ARID CYCLES

*BY S. J. EDMONDS*

## Summary

A map is presented of the South Australian sand ridge deserts and a detailed description given of the dune morphology. The mode of origin of the ridges is analysed and the conclusion reached that a channelling action, accompanied by shepherding of loose sand, has been the principal element responsible for the evolution of the corrugated desert landscape.

Thus it is proposed that the dune systems are to be classified in the main as *windrifts*. The numerous playa lakes occurring within and bordering the deserts are similarly believed to be due essentially to deflation during the Quaternary Arid Cycles; observations clearly show that excavation rather than deposition has occurred despite their endoreic setting. The composition of the desert floors is reviewed, and it is shown that the sand ridge belts are limited to areas featuring a mantle of unconsolidated Early Quaternary deposits which would be readily liable to windrift development. While the prevailing winds of the present day do not everywhere account for the pattern of the sand ridges, there is a close correlation of ridge trends and the predominating strong wind direction recorded at inland meteorological stations.

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By D. King

[Read 10 September 1959]

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## INTRODUCTION

A striking feature of the existing South Australian physiography is the advanced development and uniformity of the sand ridge formations covering vast areas of the interior. These aeolian landscapes provide ample proof of the role of the wind as a major transporting agent during the Quaternary Aridities,[*] a feature which has been commonly described in earlier works. The primary effect of the wind as an erosional agent and the resulting landforms have, however, not been considered to the full extent which they deserve in the South Australian example.

One of the main objectives of this contribution is to illustrate that aeolian effects, both erosional and transportational, have been principal elements in the evolution of the landforms which now characterise the arid interior of the State. In particular, it is suggested that deflation has played a direct role in dune formation and in the excavation of the extensive system of playa lakes bordering and accompanying the dune belts; deflation also contributed to some extent in the dissection of the inland plateaux and gibber plains, and in remodelling bedrock inliers within the desert provinces.

A map of the South Australian desert sand ridges is presented as Fig. 1. This has been compiled from a study of all available aerial photographs supplemented by direct aerial observations of the writer and others (Bennett, 1935; Madigan, 1930) and from the few existing published descriptions. It provides a reliable record of the overall distribution of the sand ridge deserts, and also shows diagrammatically the relative abundance, the orientation and the general planimetric forms of individual dunes comprising the various desert provinces. Other topographic and climatic elements which influence the study

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[*] Three distinct Quaternary Arid Cycles have been recognised as a result of soil studies in the arid zone of Australia (Jessup, 1958).

of the sand ridge deserts are also indicated. These include the principal ranges of bedrock hills, the dissected inland plateaux, the various centres of lagoon-type internal drainage, and wind analyses based on Bureau of Meteorology recordings from widely scattered weather stations. The broader orographical subdivisions, and present-day climatological data are summarised in the inset on Fig. 1.

The sand ridge deserts cover a total of 145,000 square miles, thus embracing more than a third of the total area of South Australia. Together with the adjoining sand ridge areas of Western Australia and Northern Territory, they comprise one of the most extensive and perfectly developed systems of desert dunes existing in the world today.

The South Australian dune systems lie within two broad provinces. One is in the north-east of the State, where the greater part is known as the Simpson Desert. The other, the Great Victoria Desert, occupies the western part of the State, being portion of the vast Desert Tableland extending into Western Australia. The two dune provinces approach each other between latitudes 26 and 31, where they are divided by a dissected plateau up to one hundred and fifty miles wide characterised by the "breakaway" (or tent-hill) erosional forms.

The formation of the sand ridge deserts probably occurred in several stages during the Quaternary Arid Cycles. In the Lake Eyre region, a gradual deterioration in climate to aridity is testified by interbedded gypsum layers and an assemblage of fossils of a brackish-water facies in the Late Pleistocene—Early Recent stratigraphic record, while it can also be clearly demonstrated that dune formation post-dated deposition of these particular beds (King, 1956).

In Pleistocene time, prior to the onset of aridity, pluvial conditions had prevailed throughout the interior. Extensive lakes and flood plains in the vast lowland areas received detritus from the bedrock ranges and from dissection of the Tertiary tableland to the breakaway forms of the existing marginal desert areas. As desiccation reached a climax and lacustrine and fluviatile sedimentation diminished, this mantle of unconsolidated Pleistocene waste—which, we can expect from the environmental changes, would have been sparsely vegetated —was remodelled by wind erosion into the sand ridge deserts.

In both provinces the dunes consistently assume the form of elongated ridges, and although their spacing and magnitude may vary considerably in different localities, locally they are always regular in magnitude and planimetric pattern.

It will be observed that dunes of an inland type are also widely developed in the northern Murray Basin, east of the Mount Lofty Ranges. These, however, are subordinate forms not characteristic of a truly desertic environment. Excluded from consideration are the stranded marine shoreline dunes of the south-east, and the calcareous aeolianite mantle fringing the coastline of Yorke and Eyre Peninsulas.


## PHYSIOGRAPHY OF THE SAND RIDGES

The Simpson Desert, named and defined by Madigan, embraces an area of 43,500 square miles lying between the Finke River on the west and the Queensland border on the east, and extending from the Marshall River in latitude 23°S. (Central Australia) southward to Lake Eyre in latitude 28°S. This region embraces most of the north-eastern desert dune province, the exceptions being an extension southerly to Lake Frome and a relatively small area south-west of Lake Eyre. Arid conditions prevail today in the Simpson Desert, the greater part receiving less than five inches annual rainfall.

SAND RIDGE MAP
OF
SOUTH AUSTRALIA

50   0   50   100   150   200 Mls.

WESTERN AUSTRALIA

MUSGRAVE RANGE

EVERARD RANGE

OODNADATTA

GREAT VICTORIA DESERT

TIETKENS PLAINS

NULLARBOR PLAIN

OOLDEA

L. Everard

CEDUNA

GAWLER RANGE

EYRE PENINSULA

Lake Eyre North

SIMPSON DESERT

INNAMINCKA

L. Callabonna

LEIGH CREEK

L. Frome

WOOMERA

L. Torrens

L. Gairdner

PORT AUGUSTA

FLINDERS RANGE

OLARY

MURRAY PLAINS

ADELAIDE

QUEENSLAND

NEW SOUTH WALES

VICTORIA

Orographic divisions
Over 1000'
500 to 1000'
Under 500'

Rainfall, average annual in inches — 8 —

Evaporation, average annual in inches — 70 —

Sand ridge formation
Desert sand ridge-ground plan shown diagrammatically
Beach ridge (of south-east)
Playa lake
Dissected tableland, "breakaway"
Bedrock Hills, principal ranges
Wind rose, annual percentage frequency
afternoon winds exceeding 18 m.p.h.
Key to meteorological stations
1. Ceduna   2. Woomera   3. Adelaide   4. Broken Hill
5. Leigh Creek   6. Oodnadatta   7. Forrest

Fig. 1.—Sand Ridge Map of South Australia.

The sand ridges of the Simpson Desert are developed to an especially high order of magnitude and symmetry, for which reason the region has proved most attractive for geomorphological researches. The physical characteristics of the dunes and the dune belt as a whole have been fully described in earlier published works and maps (Madigan, 1936, 1946; King, 1956) and are only briefly summarised here.

In the Simpson Desert proper there are individual dunes that exceed 200 miles in length. They vary in height from 40 to 100 feet, lie 300 to 500 yards apart, and are slightly asymmetric in section with the steepest slope facing easterly to southerly, depending on trend. The axial trend of the ridges varies throughout the Lake Eyre Basin in a broadly arcuate manner, from north-easterly in the area west of Lake Eyre to meridional in the Simpson Desert, and to approximately east-west in the south-east portion of the Basin near Lake Frome. The dimensions and perfection of the ridges also vary gradationally, changing from short and indefinite formations west of Lake Eyre to the bold, corrugated relief of the Simpson Desert.

An outstanding morphological feature is the widespread occurrence of dune convergence, despite the otherwise rigid parallelism of the sand formations. The convergences are represented in ground plan by an asymmetric Y, which in every case points to the north to east quadrant—depending on trend.

In one locality it has been shown by boring that the dunes are not entirely composed of sand drift, but that the drift is superimposed on similar elongated ridges of older Pleistocene sediments which form the desert pavement in this region (King, 1956), indicating erosion of some twenty feet of the desert floor from the interdune corridors.

The second province, the Great Victoria Desert, comprises an area of some 70,000 square miles in the north-western portion of the State, together with an adjoining area of comparable size in Western Australia, all featuring a monotonous repetition of sand ridges with interspersed playa lakes and a complete absence of surface drainage courses. Rainfall in the desert is between five and eight inches annually. A narrow belt of sand ridges of the same system extends from the desert province into higher rainfall areas of Central Eyre Peninsula.

The sand ridges of the Great Victoria Desert have the same general forms as those of the Simpson Desert, although panoramically they are less spectacular because of an established vegetation cover. The ground plan of the dunes in this area has been compiled from R.A.A.F. photographs of the Everard Range and the Ooldea — Coober Pedy areas, supplemented by data of the Mackay Aerial Survey (Bennett, 1935) and observations by the writer while taking part in airborne geophysical surveys (Bureau of Mineral Resources, 1956) covering most of the desert area.

The spacing of the ridges varies appreciably in the different parts of the desert, being most commonly of the order of a quarter to a half a mile, but in places, and especially near the margins of the desert, as little as one sixth of a mile. The usual height is from 30 to 40 feet and the length may exceed twenty miles.

The orientation of the ridges changes gradationally from approximately east-west near the W. Aust.—S. Aust. border, to north-easterly between Coober Pedy and the Everard Range, finally swinging to west of north in the Simpson Desert. On Eyre Peninsula they trend south-easterly. Tietkens Plain marks the divide between the north-easterly and south-easterly trending dune systems. The southern flanks of the ridges are generally the steepest.

Dune convergences are common throughout the Great Victoria Desert and

the resulting V or U-shaped planimetric forms are without exception open to the west (Plate 1, upper figure).

Vegetation is notably sparse throughout the Simpson Desert province, and is represented chiefly by the non-aggressive *Spinifex* and *Triodia*, while in the Great Victoria Desert there are also stunted acacias (Mulga, Myall) and other drought-resistant plants.

As a general rule, the corridors of the ridges support the densest vegetation, while the crests are normally devoid of growth with local patches of live sand. The meagreness of plant growth in most places gives the general impression that dune development has become essentially stabilised, but minor scale sand migration is still taking place and might readily recur on a grand scale in the event of but a slight climatic deterioration.

## CLASSIFICATION AND ORIGIN OF THE SAND RIDGES

As a result of detailed studies and comprehensive publications by C. T. Madigan (1936, 37, 38, 46), the ridges of the Simpson Desert have become widely known, and are now accepted in overseas literature as classical examples of *longitudinal dunes*—which may be generally defined as elongated ridges *composed entirely of drift sand* lying parallel to the causal wind, to the leeward of the sand source (Bagnold, 1941; Price, 1950) and believed by some (Melton, 1940) to be accumulations in the lee of obstacles.

In his valuable records, Madigan clearly indicated his appreciation of the longitudinal windrift phenomenon and its possible role in the formation of the Simpson Desert ridges. He preferred, however, to consider the adjacent dissected tableland country as the principal sand source, and suggested that the dunes were composed entirely of transported material forming a shallow veneer upon a presumed hard desert floor. The following extracts from his works (1936) are clearly relevant in the light of more recent observations, which demonstrate the dominant role of wind channelling rather than shepherding of loose sand in the evolution of the sand ridge landscape:

"In a private communication M. Aufrere has informed me that his essential theory of the formation of longitudinal dunes is that they are derived from forms similar to the *caoudeyres* of Gascony, which begin as wind-made excavations in the sand similar to the *fuljes* . . . of the Nefud of Arabia and elsewhere. These excavations, accompanied by a piling of the excavated sand on the downwind side and a trail of sand left behind on each side of the excavation, extend downwind until they form a U-shaped dune, open to the windward, and, when the closed portion of the U disappears, become a pair of parallel dunes, longitudinal or parallel to the wind direction. . . ."

"The sand ridges of the south-western part of the Indian Desert, apart from their height, bear a much stronger resemblance to those of Australia. . . . The longitudinal form of the ridges was ascribed by Blanford to the particularly strong force of the winds, which blow for long periods at 30 miles an hour. . . . Blanford considered that the Indian Desert was at one time more thickly covered with sand and that the hollows between the sand ridges were due to denudation by the wind, so that the ridges would be residual rather than heaped up by the wind. This is an entirely different point of view, but it has much to recommend it could it be established that there had once been an accumulation of sand hundreds of feet thick."

Indeed, as previously described, a section revealed by boring in the sand ridges and corridors near Lake Eyre has shown that the formation of ridges here has essentially resulted from wind channelling of the desert floor, and the

consequent corrugations have been accentuated by deposition of the released drift material along the ridge crests. While not denying that some of the sand ridges, especially at the desert margins, may be longitudinal-type accumulations of drift sand, the present study has led the writer to believe that residual or *windrift dunes*, as observed to occur at Lake Eyre, are predominant among the sand ridge forms occurring throughout the South Australian desert provinces.

In his classification, Melton (1940) states that windrift dunes are characteristic of arid areas underlain by deep sand, with a non-aggressive vegetation and featuring strong winds of constant direction.

"Many (windrifts) are a mile or more in length, though the width is only a few hundred feet. The sand rim is a hairpin or elongated chevron shape, opening towards the wind. In the best developed windrifts the wings are quite parallel throughout their extent. In the most common form, however, the wings gradually approach each other in the down wind direction, indicating that the blowout gradually became smaller as it migrated."

A reference to the accompanying aerial photographs of the dune systems (Plate 1) and to those previously published (King, 1956) will demonstrate that the windrift principle provides a compelling explanation of the various converging sand ridge patterns. Further supporting criteria are the numerous claypans of the interdune rifts which are clearly a result of wind erosion, and the actual example of wind flutings observed to be taking place in some present-day windswept areas near Lake Eyre.

The composition of the desert floors would certainly be a fundamental condition determining areas liable to windrift dune activity, an essential prerequisite being a thick mantle of poorly cemented or friable sandy material which in a dry state can be readily eroded by the wind. It is surely convincing evidence that the main dune systems are in fact restricted to areas featuring a mantle of poorly consolidated Early Quaternary fluviatile deposits (Stephens, 1938) and are best developed in the Simpson Desert where the mantle sediments —unconsolidated gypseous sand, sandy clays and fine sands (King, 1956)— are especially well represented. Hence we also have a sound explanation why the sand ridges of the Great Victoria Desert terminate precisely at the margins of the Nullarbor Plain, which is capped by hard silicified limestone, and why in Western Australia it has been observed that inland sand ridges are confined to areas underlain by sedimentary rocks, a feature described by Talbot and Clarke (1917) in their own words as follows:

"It is difficult to account for the fact that, while the sand derived from granite tends to spread out over a comparatively level surface, in the sedimentary area . . . it is piled in long ridges."

In a personal communication, D. M. Traves states that microscopic analyses of samples from the south-western Canning Basin of Western Australia (part of the Great Sandy Desert) has revealed that the heavy mineral composition of the sand ridges closely corresponds from place to place with that of the underlying or nearby desert pavements; thus he concludes that no appreciable migration of sand has been involved in the formation of the ridges.

The sand ridge provinces are apparently independent of the regional ground relief shown on the orographic map of the State (Fig. 1).

## CLASSIFICATION AND ORIGIN OF THE DESERT PLAYA LAKES

The larger salt lakes and playa lakes of the interior of the State, especially Lakes Frome, Callabonna, Blanche, Gregory, Eyre and Torrens, have commonly been described as shrunken relicts of exoreic drainage systems believed to have existed under pluvial conditions just prior to the Recent Arid Cycle (Howchin,

1913). It is to be understood, however, that all the playas of the north-east lie within a vast area where stratigraphic records reveal active lacustrine sedimentation during the Pleistocene and possibly Early Recent (Mawson, 1934; King, 1956), but the direct association of the existing playa lakes with the Pleistocene physiography is a generalisation which is considered untenable in view of further researches outlined hereunder.

Geological and topographical studies conducted by the author in the Lake Eyre Basin in 1953 have clearly proved in the case of Lake Eyre that lake development has post-dated all fluviatile sedimentation in the area, the lake as we know it today being a very youthful feature formed by wind erosion during the Recent aridity, and thus comparable in origin with the great Qattara depression of the Libyan Desert (Ball, 1927).

Lake Eyre North is approximately 25 feet below L.W.O.S.T. Port Adelaide (Bonython, 1955) and would therefore be expected to have silted up appreciably under the prevailing conditions of endoreic drainage. On the contrary, excavation rather than deposition has occurred as shown by the occurrence of undisturbed Early Recent *Coxiella-bearing* sediments in the shoreline cliffs at a height of 36 feet above the lake bed, which itself comprises an eroded platform of Quaternary sediments of a lower stratigraphic level, and is generally free of any newer silt material. This is so, despite periodic floodings of the lake such as that experienced in 1949-50, and earlier floodings marked by a series of stranded beach ridges observed along the southern shores.

The formation of Lake Eyre by deflation would be materially assisted by wind-generated wave action during periodic floodings, especially as regards the lateral growth of the shorelines. Indeed, it will be observed that the larger lakes of this north-east province are the ones receiving drainage from distant higher rainfall areas.

In proposing an aeolian origin for all the playa lakes of the interior, a more radical explanation arises for the highly asymmetrical form of the greater Lake Eyre "drainage system", and the seemingly paradoxical condition (Browne, 1934) that the lakes are largest and most abundant in the driest parts of the State.

The sandy fractions removed from the playa depressions are believed to have contributed to the deposits of "live" sand occurring on the crests of the accompanying sand ridges. Independent soil studies have revealed that finer fractions of deflated material provided the principal source of the soils existing in the arid portions of Australia (Jessup, 1958).

Fig. 1 illustrates that there are scores of other isolated playa lakes and claypans of appreciable size lying among the sand ridge deserts to the east of Lake Eyre and extending northwards into the Simpson Desert. Lake Kitta-kittaoola (lat. 28°, long. 138°) is one of the largest, measuring about 25 miles long and up to 5 miles wide.

These lagoons have remarkably regular shoreline characteristics, all of which bear testimony to a purely aeolian origin; the northern (or leeward) margins are bare and fluted surfaces of arcuate shape, concave to the south, and featuring a wind-swept rim, beyond which there is a gradual restoration of the sand ridge formations. The southern shorelines are marked by classical cuspate indentations in which the cusps correspond with the steep termination of dune ridges, while the intermediate embayments coincide with interdune valleys (Plate 1, lower figure). These cuspate playa lakes are similar in profile to the *fuljes* of the Libyan Desert, and there seems little doubt that they are of similar physical origin.

Identical cuspate playas have been observed by the author among sand

ridges in the Great Victoria Desert, along the Western Australian border between latitudes 27°30' and 29°30'; others have been described from the Great Sandy Desert of north-west Western Australia (Traves *et alia*, 1956) and are considered by these authors to have "probably formed in the same arid period as the sand dunes".

Another lagoonal form which can similarly be attributed to strictly aeolian origin is the typically small oval-shaped claypan which occurs abundantly in the interdune valleys throughout all the sand ridge deserts of the State, and which reflect wind excavation of the interdune corridors as proposed previously in this paper. These corridor claypans are usually less than a mile in their largest dimension and are now commonly partly vegetated. Although individually too small to be shown on the State maps, the dune corridor claypans would collectively cover say five per cent of the sand ridge desert areas.

The relative abundance and dimensions of these claypans are regarded by the writer as a measure of the maturity of sand ridge development. Their presence indicates that deflation has reached a base level below which further erosion is inhibited by ground moisture. This condition would now appear to apply generally to the various types of playa lakes of the Simpson Desert.

In briefly considering the extensive lagoonal depressions of northern Eyre Peninsula, including the larger Lakes Everard, Gairdner and Gilles, it is true that the lake beds are in most places composed of a weathered bedrock pavement (predominantly Precambrian) with negligible silt accumulations—which also often applies in similar basement playa lakes of Salinaland, Western Australia (Jutson, 1934). Again there is evidence of the major role played by deflation in the course of the Quaternary Arid Cycles.

## CAUSAL WIND REGIME

In proposing the windrift rather than longitudinal mode of origin for the elongated sand ridges of the South Australian deserts, no modifications are required in reviewing evidence of the causal wind regime as both are basically leeward growth phenomena. A difference arises, however, in considering the origin of the Y-shaped convergences formerly regarded (Madigan, 1936) to be due to infrequent gusty side winds capable of locally deflecting the smaller bulk of sand at the leeward end of the ridges. The suggestion here is that the convergences mark the termination of individual rifts, which might readily become inactive as the result of more effective erosion and growth of adjacent troughs. Thus two wings of a "captured" windrift may unite in an inverted V or crescent and continue to the leeward as one wing of a larger rift.

As previously described, dune convergences—or windrift terminations—are common to all the South Australian desert tracts, and not one example of orientation opposed to the trends shown in Fig. 1 have been observed by the writer. These forms, open to the windward and pointing to the leeward, thus provide a unique physiographic index of Early Recent wind activity. The windrift pattern indicates that the causal winds were westerlies in the Great Victoria Desert, with a gradational change to south-westerlies north of Woomera, and swinging through southerlies to south-south-easterlies in the Simpson Desert; north-westerlies (Eyre Peninsula) and westerlies (east of the Flinders Range) were operative south of latitude 30°.

The cuspate playa lakes of the Simpson Desert are similarly consistent in shape and orientation and reflect erosional characteristics produced by southerly winds. A few of the playa lakes in the Great Victoria Desert have identical cuspate shorelines on the windward (western) margins.

An interesting question which arises from the sand ridge study is whether the Early Recent wind record is comparable with the present day wind regime. Madigan (1936) associated the dune trends throughout the whole of Australia with the prevailing wind directions based on a mean annual pressure map of 1910. He was able to provide confirmatory morphological evidence of this correlation in the Simpson Desert, but his conclusion that the Great Victoria Desert dunes were formed by the prevailing south-east trade winds is inconsistent with the detailed ridge pattern here recorded.

While denying any overall association of dune trends and prevailing winds such as those of today, the writer nevertheless considers from evidence outlined below that the present wind regime can satisfactorily account for the sand ridge systems providing that a discrimination is made between *prevailing wind* and *predominating strong wind* directions.[*] The frequency of low velocity winds has a considerable effect upon the geometry of the annual wind roses but little or no bearing on deflational erosion and transportation of sand.

The significance of this distinction is illustrated by the following wind recordings at Woomera over a three-year period.

| Wind Velocity M.P.H. | Wind Frequency Per Cent | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | N. | N.E. | E. | S.E. | S. | S.W. | W. | N.W. |
| Less than 20 | 12 | 8 | 3 | 14 | 24 | 20 | 10 | 9 |
| 20-35 | 27 | 4 | 2 | 3 | 19 | 19 | 21 | 5 |
| Greater than 35 | 26 | --- | | · | 16 | 22 | 18 | 18 |

Wind roses based on the percentage frequency distribution of afternoon winds exceeding 18 m.p.h. at principal meteorological stations in South Australia are shown in Fig. 1 and further particulars are given in Table 1.

TABLE 1.

METEOROLOGICAL RECORDS USED IN COMPILATION OF WIND ROSES

| Station | Period | Time (Hours) | Velocity (M.P.H.) | | Predominating Wind Direction Frequency% | |
|---|---|---|---|---|---|---|
| 1. Ceduna | 1942-46 | 14-30 | exceeding | 20 | S | 20·4 |
| 2. Woomera | 1949-53 | " | " | " | WSW | 18·7 |
| 3. Adelaide | 1936-40 | 15·00 | " | 18 | SW | 15·9 |
| 4. Broken Hill | 1942-47 | " | " | " | W | 26·2 |
| 5. Leigh Creek | 1952-54 | 14-30 | " | " | SW | 21·6 |
| 6. Oodnadatta | 1944-48 | " | " | 15 | S | 16·8 |
| 7. Forrest | 1945-49 | 15·00 | " | 18 | W | 16·8 |

It will be seen that in the interior there is a generally close correlation of predominating strong wind directions and the causal wind directions proposed by analysis of the sand ridge map. The only anomalous case is at Ceduna (and to a lesser extent Adelaide), where the wind records are probably influenced by variations due to the coastal setting.

[*] Originally suggested in a personal communication by B. Mason, Senior Meteorologist of the Bureau of Meteorology (S.A.).

The wind roses shown similarly account for the disposition of the *transverse* gypsum sand ridges which occur adjacent to saline swamps and playas in parts of the State; believed to be formed by westerlies in the Murray Plains at Cooke Plains and Craigie Plains, and at Lake Bumbunga, north-westerlies at Lake Fowler, and south-westerlies at Lake MacDonnell near Ceduna.

Some strikingly severe dust and sand storms are promoted under present-day conditions by strong northerly winds, which are well represented on the wind roses of the desertic interior. These northerly winds would undoubtedly modify the forms assumed by accumulations of live sand, but it has been observed in the Simpson Desert that the cooler southerly winds have a much greater effect on actual sand migration (Madigan, 1936).
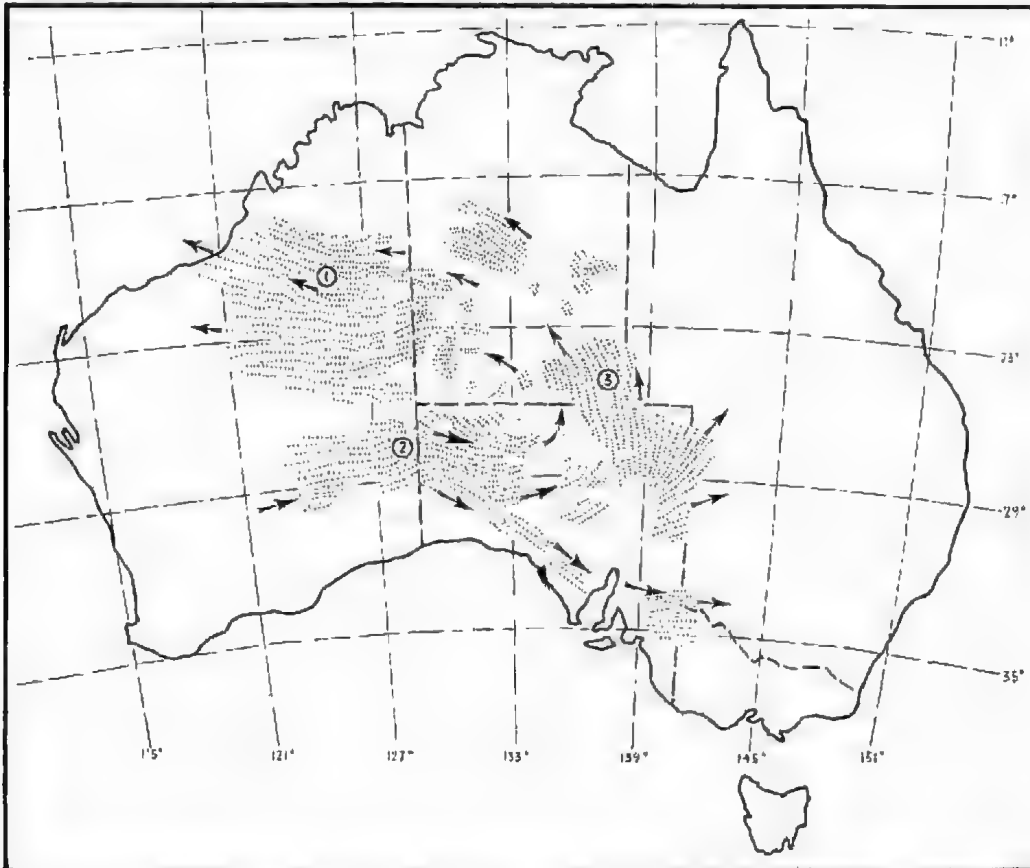


Fig. 2.—Generalised map showing the distribution and orientation of Australian desert sand ridge formations. The arrows indicate the direction of Y-shaped ridge convergences (or rift terminations) which are represented throughout the desert provinces and are considered to be coincident with the causal wind pattern.

1. Great Sandy Desert.   2. Great Victoria Desert.   3. Simpson Desert.

A study of published data on the whole of the Australian desert zone has shown that the morphological characteristics of the sand ridges and playa lakes as observed by the writer in South Australia are also applicable in the desert provinces of adjoining States. The distribution and orientation of the desert sand ridges throughout the Continent are shown on Figure 2, where also is given an interpretation of the causal wind regime based on the principles outlined in this paper.

# ACKNOWLEDGMENTS

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The drafting of the text figures was undertaken by staff of Rio Tinto Australian Exploration Pty. Ltd., by kind permission of the Managing Director, Mr. S. B. Dickinson. Dr. B. Campana, Senior Geologist of the same Company, is to be credited with much helpful guidance during the preparation of the paper. Thanks are also due to Professor J. A. Prescott for his assistance in finalising the text and figures for publication.

Meteorological records and interpretations were supplied by Mr. B. Mason, Senior Meteorologist of the Bureau of Meteorology (S.A. Division) and by the Director of Meteorology, Melbourne. The Division of National Mapping of the Department of National Development, Canberra, assisted by suggesting and supplying relevant cartographic data.

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Converging dune ridges of the Great Victoria Desert. View looking north from near Ooldea, South Australia. There are six ridges per mile in this area.
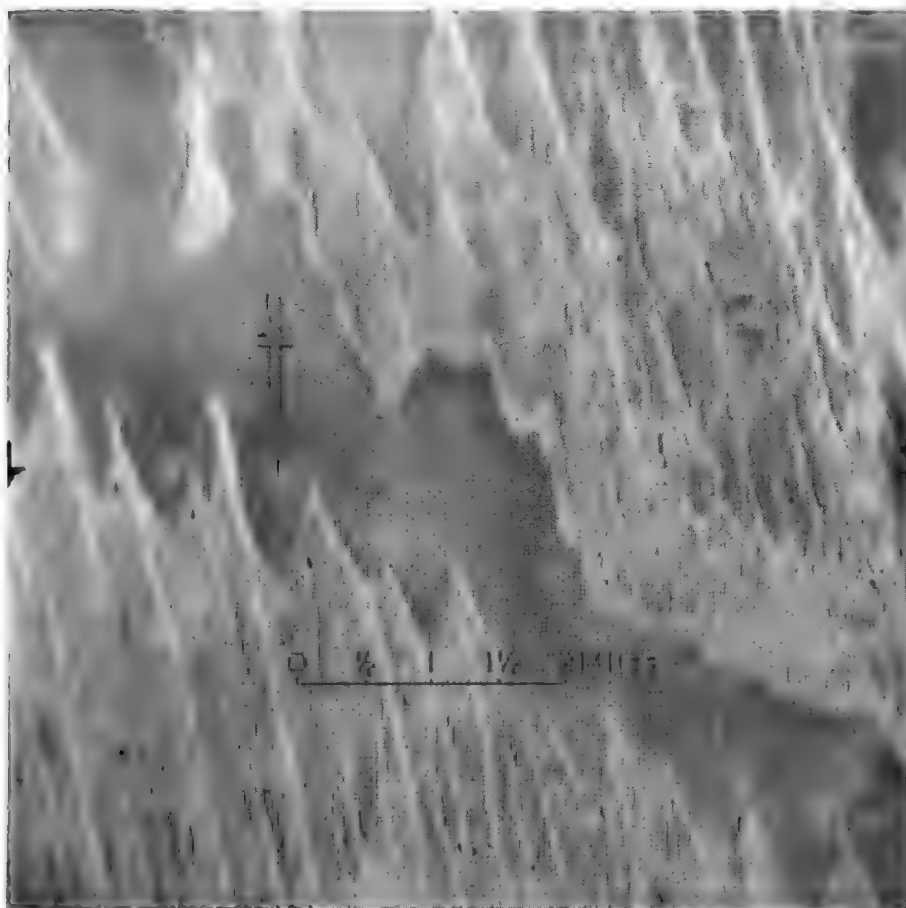


Shores of a cuspate playa lake to the east of Lake Eyre North.

# DISTORTED COWRZES

BY BERNARD C. COTTON, F.R.Z.S.

## Summary

The paper records some distorted cowries in the South Australian Museum collection.

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[Read 8 October 1959]

## SUMMARY

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### Lyncina lynx caledonica Crosse

*Cypraea caledonica* Crosse 1869.  Journ. de Conch., Vol. 17, p. 41, pl. 1, fig. 1.

A series of five specimens of "*C. caledonica*" (D. 3920), the name given to a distorted form of *L. lynx*, from New Caledonia, range from the *C. caledonica* form to almost typical *C. lynx*.  The largest specimen agrees exactly in size with the holotype of *C. caledonica*, height 59 mm. × width 24 mm. × dorso-ventral 29 mm. The second largest specimen is 56 mm. × 25 mm. × 25 mm. The remainder are smaller and merely slightly narrower in proportion than typical *C. lynx*. Another series of eight specimens (D. 3917), from the same locality, are somewhat irregularly weakly pustulose on the margins, but are nearer to typical *C. lynx* than the distorted form, both in colouration and shape.

### Ornamentaria annulus noumeensis Marie

*Cypraea noumensis* Marie 1869.  Journ. de Conch., Vol. 17, p. 18, pl. 2, fig. 6.

Two mature specimens, from Noumea, examined are miniatures measuring, length 15 mm. × width 9 mm. × dorso-ventral 7 mm., and 14 mm. × 8 mm. × 6 mm. The holotype is 30 mm. × 15 mm. × 13 mm.

### Monetaria moneta barthelemyi Bernardi

*Cypraea barthelemyi* Crosse 1861.  Journ. de Conch., Vol. 9, p. 48, pl. 1, figs. 3, 4.

Holotype measurement of this New Caledonian species is height 37 mm., width 22 mm.

Our series of thirteen shells grade from typical *C. barthelemyi*, to normal *C. moneta*.  D. 3529(13).

The most distorted pair measure, height 31 mm., width 17 mm., dorso-ventral 12 mm., 34 mm. × 18 mm. × 15 mm.

### Bistolida stolida crossei Marie

*Cypraea crossei* Marie 1869.  Journ. de Conch., Vol. 17, p. 16, pl. 1, fig. 3.

Our three specimens are from Noumea, and are shorter than the holotype. Height 38 mm., width 19 mm., dorso-ventral 16 mm., 38 mm. × 20 mm. × 15 mm., 37 mm. × 19 mm. × 15 mm.  D. 3587(3).

The holotype measurements are 43 mm. × 20 mm. × 15 mm.

### Arabica arabica niger Roberts

*Cypraea niger* Roberts 1885.  Tryon's Manual Conchology, Vol. 7, p. 174, pl. 8, fig. 3.

A series of seventeen specimens grade from the typical narrow, high, dark *C. niger* through normal shaped dark specimens to slightly narrower lighter

coloured shells.  The narrowest and most distorted specimen measures, height 55 mm., width 29 mm., dorso-ventral 27 mm.  The surface is pustulose and the colour dark blackish-brown.  D. 3930(10).  D. 3931(4).

### Notocypraea declivis Sowerby

*Cypraea declivis* Sowerby 1870.  Thes. Conch., Vol. 4, p. 31, figs. 287, 328, 329.

This sinistral specimen of *Notocypraea declivis* is briefly referred to in the "Journ. Malacological Soc., Aust.", No. 2, p. 9, 1958.  D. 14602(1).

The shell is typical in colour and noticeably wider than the Western Australian *N. occidentalis* Iredale 1935, as figured by the present author in the above publication.  The height is 22 mm. and width 19 mm., and dorso-ventral 11 mm.

Since writing the above, Mr. R. V. Drogemüller mentioned a sinistral specimen of *N. verconis* taken at Port MacDonnell by Ian Carrison.

*Notocypraea declivis* Sowerby, sinistral. Tasmania.

# OBSERVATIONS ON THE DIET AND SIZE VARIATION OF AMPHIBOLURUS ADELAIDENSIS (GRAY) (REPTILIA: AGAMIDAE) ON THE NULLARBOR PLAIN

*BY* MICHAEL J. TYLER

## Summary

Forty-one specimens of *A. adelaidensis* (Gray) were captured and the stomach contents examined. Measurements of the body length of the lizards were recorded, and the variation suggests that the life span in the natural environment does probably not exceed two or three years. A general description of the specimens captured was made, and the taxonomic problems associated with the original description are discussed. From analyses of the stomach contents, it is concluded that *A. adelaidensis* is probably a discriminate feeder.

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Forty-one specimens of *A. adelaidensis* (Gray) were captured and the stomach contents examined. Measurements of the body length of the lizards were recorded, and the variation suggests that the life span in the natural environment does probably not exceed two or three years. A general description of the specimens captured was made, and the taxonomic problems associated with the original description are discussed. From analyses of the stomach contents, it is concluded that *A. adelaidensis* is probably a discriminate feeder.

## INTRODUCTION

The food items selected by large reptiles may be determined by direct observation upon the animals in their natural habitat, or examination of faecal matter (Leydig, 1896). For smaller species, where it is impossible to identify at a distance the food items ingested, different methods are employed.

Acceptance or refusal of food items offered to a captive specimen may provide interesting data, but the obvious limitations, due to the reduced variety of available prey, imposed upon the animal, could result in the acceptance in captivity of prey normally rejected in the natural environment.

By far the most satisfactory method, which has been employed for both the Reptilia and Anura, is the examination of the stomach contents of a series of specimens captured at random in the field.

Food items selected or rejected by Australian lizards have been mentioned by several writers, the earliest probably being an observation by Krefft (1871), who noticed that *Tiliqua (Cyclodus)* sp., "feeds, besides insects, upon the berry called 'jee-bung', and also on other berries and leaves".

More recently Coleman (1945) reported that *Tiliqua (Trachysaurus) rugosa* (Gray) and *Amphibolurus barbatus* (Cuvier) in captivity ate soft fruits, dandelions and other flowers, snails, eggs (previously broken), milk, bananas and raw beef; similar observations upon the former species having been previously mentioned in a publication by Longley (1940). The latter author also records *Gymnodactylus spyrurus* (Ogilby) accepting caterpillars, isopods, the native cockroach *Panesthia laevicollis* and an introduced species quoted to be *Blatta americana* (presumably a confusion between *Blatta orientalis* and *Periplaneta americana*), but rejecting the vine moth *Agarista glycinea*. *G. platurus* is stated to eat similar food items, and was also found to reject both the larvae and adults of *A. glycinea*.

A very interesting observation by Davey (1944), revealed that *Moloch horridus* (Gray) rejected certain species of ants but accepted others. Those rejected were stated to be *Iridomyrmex detectus*, *I. nitidus*, *Ectatomma metallicum*, *Monoromorium*, *Camponotus* and *Pheidole* spp., whilst *Iridomyrmex*

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*rufoniger* was accepted at a daily consumption rate estimated by the writer at 1,350 specimens.

Neither previous papers mentioning stomach analyses of Australian specimens captured in the field, nor any record of food items ingested by *Amphibolurus adelaidensis* (Gray) (The Queen Adelaide Dragon) have been traced by the writer of this paper.

For reasons discussed later, the distribution is a matter of some conjecture. It has apparently been recorded in Western and South Australia, Victoria and Tasmania (Zietz, 1920; Lord & Scott, 1924; Waite, 1929).

Large numbers were observed by the writer upon the Nullarbor Plain at the Commonwealth Railways fettlers' camp "639 miles" W.N.W. of Port Pirie during the period 6th-15th February, 1959. In this region *A. adelaidensis* was the predominant species, being associated with *Gymnodactylus milii* (Bory de Vine.), and *Tiliqua rugosa* (Gray).

## METHODS

*A. adelaidensis* lives either singly or gregariously in short burrows beneath large rocks or flat stones from which they emerge in search of food. If disturbed whilst upon the surface of the ground, the lizards return to the burrow with considerable speed. It was observed in the course of collecting that if the rock covering the burrow was then removed, the lizard did not rely upon escape by fleeing from the intruder, but searched haphazardly for a new retreat within the immediate vicinity, frequently selecting the instep of the writer's shoes. Young specimens, however, remained in the exposed burrow, relying for protection upon their excellent camouflage which closely resembled the sandy soil. Forty-one specimens were subsequently captured at random by hand with very little difficulty.

Shortly after capture the specimens were killed with the fumes of ammonia or carbon tetrachloride or by pithing. Measurements of the body, dorsally, from the external nares to the apex of the tail and, ventrally, from the anterior tip of the upper jaw to the vent were recorded.

The body viscera were examined for the presence of anatomical abnormalities and parasites, whilst the stomach contents were removed and the food items, where insects, identified to the order and if possible to the family.

## OBSERVATIONS

(a) *Size variation*

The sizes of the specimens illustrated in the form of a histogram in Figure 1 are ventral measurements of the body from the anterior extremity to the vent, and not the total length of body plus tail, because it was observed that the tails of several of the mature specimens had been previously severed and were in various stages of regeneration.

The largest total lengths recorded were: 135 mm., 142 mm., 154 mm. males; 159 mm., 160 mm., 172 mm. females.

The distribution of the sizes in the histogram falls into two clearly defined, apparently homogeneous groups which have been lettered A and B. The specimens in A are all juveniles which will have hatched from eggs laid by group B in the previous season. A is therefore homogeneous in sexual immaturity since all its members are incapable of reproduction. Post mortem examination of the gonads of group B revealed what was believed to be sexual maturity in all specimens and homogeneity similarly applies.

The presence of a distinct gap between the groups (only one specimen being recorded between 36-45 mm.) represents the growth made by the next preceding generation during the winter months before the appearance of the generation seen in A, a time when no lizards are born.

Similar observations were made by Simpson and Roe (1939), who examined data compiled by Blanchard and Blanchard (1931) upon the salamander *Hemidactylium scutatum*, and by the writer (1958) upon the frog *Rana esculenta*.
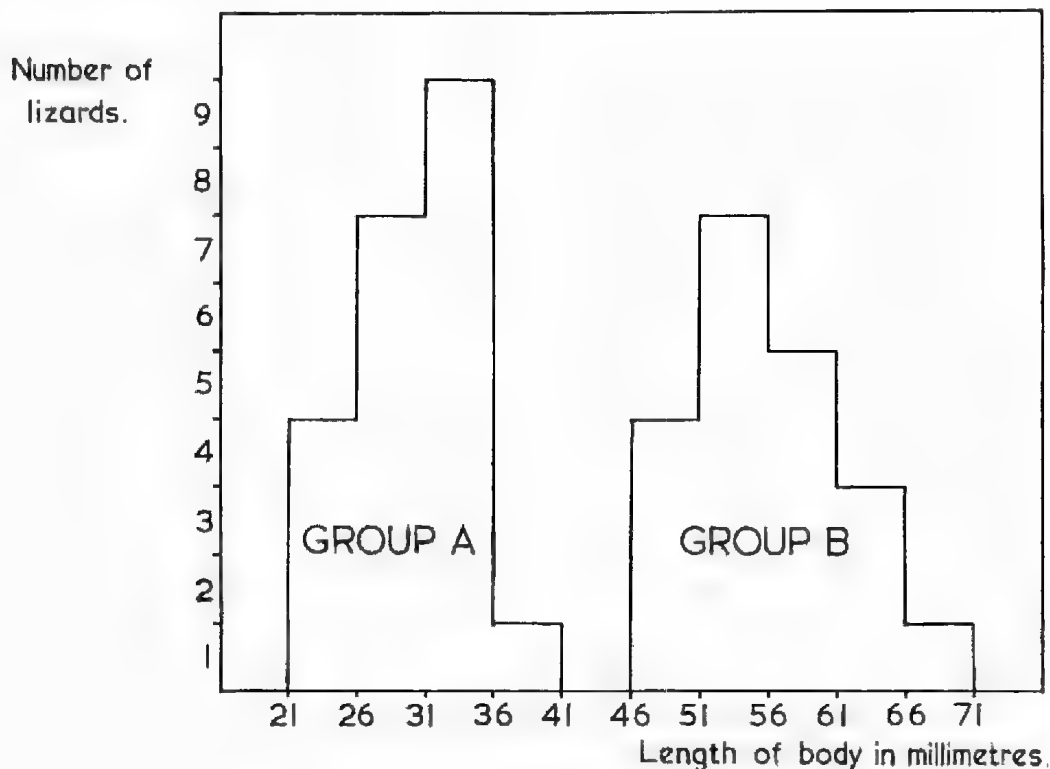


Fig. 1

The rapid initial rate of growth by *A. adelaidensis*, the increase in size during the first year, and the presence of only a single peak in B would suggest that the life span in the natural environment does not exceed two or three years, although it was previously believed that this species lived for much longer.

(b) *Food items recovered*

No apparent difference in the food items recovered from juvenile and adult lizards was recorded, and so the entire prey have been treated as a whole in the histogram (Fig. 2).

The Coleoptera consisted of single specimens of the families Staphylinidae and Tenebrionidae, whilst the Hemiptera was represented by four specimens of the family Pentatomidae and one other unidentified specimen.

Three of the Lepidoptera were adult moths, the remainder being larvae varying in size from a specimen measuring 14 mm. in length to first or second instars of approximately 1 mm. length.

The Orthoptera were all small grasshoppers (family Acrididae).

With the exception of one small parasite (family Ichneumonidae) the Hymenoptera recovered consisted of various species of ants (family Formicidae).

The remainder consisted of one fly (Diptera, family undet.) and five spiders (Arachnida, family Araneae).
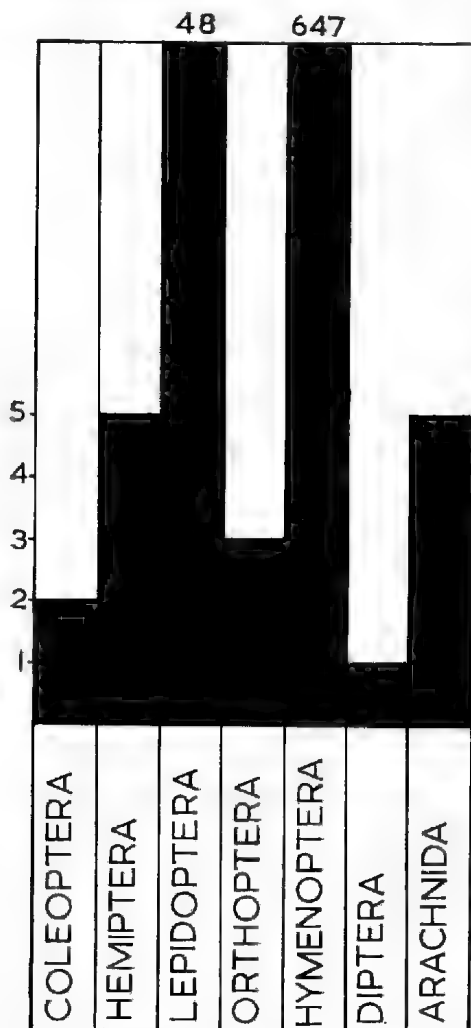


Fig. 2. Number of prey.

## DISCUSSION

(a) *Taxonomic problems arising from the original description*

The specimens upon which this paper is based are typical of the form regarded as *Amphibolurus adelaidensis* by Boulenger, 1887, and Waite, 1929.

The original description by Gray (1841) of specimens collected by Gould in the locality of the Swan River is very scant by modern standards, and is based mainly on colour pattern which, as described below, is variable. He named the specimens *Grammatophora muricata* var. *adelaidensis*.

The following description of the specimens examined by the writer on the Nullarbor Plain incorporates and elaborates those of Waite and Gray.

The adpressed hind limbs extend to or almost to the tympanum.

The scales are strongly keeled and are largest on the dorsal surface, where they appear in distinct posteriorly projecting rows on either side of the mid-line, extending from the cranium to the base of the tail. On each lateral aspect of the base of the tail is a series of outwardly projecting spines extending posteriorly for a distance in mature specimens of approximately ten millimetres, and are similar to those previously mentioned in that they also possess three spines.

The pores are either regularly situated or interrupted in the preanal region, and extend little more than half way down the thighs. The total number of pores varies between twenty and thirty, more commonly nearer the lower figure.

The ground colour on the dorsal and lateral surfaces of the body varies from grey to olive-grey. There is a series of paired, small brown, angular markings on the back which are adjacent superiorly to larger, similarly coloured, but less clearly defined markings on the dorso-lateral surface between the limbs.

The head is of a reddish-brown colouration with symmetrical dark brown markings; dark brown bars on the hind limbs are narrower and less conspicuous on the fore limbs.

The tail with a series of paired, dark brown markings of rectangular form at the base which become irregular posteriorly, and merge into symmetrical bands towards the extremity.

The ventral surface a pale cream colouration with a broad black stripe extending from the abdominal ventro-lateral surfaces, which fuses on the mid-ventral line in the region of the thorax. Black markings on the throat extremely variable, being present as an irregularly shaped patch, spotted producing a marbled appearance or completely absent.

A rapid colour change was observed in specimens placed from dark on to light surfaces and vice versa. On the dark surface the brown dorsal markings greatly increased in intensity. When placed on a white surface, the brown markings became paler, and approached a reddish-orange tint and a pattern of markings appeared that had not been observed in the field.

Three very distinct longitudinal, pale grey stripes appeared on the dorsal surface, one extending as a vertebral stripe, between the angular markings, from the base of the skull posteriorly to the base of the tail, where it was replaced by a series of pale brown bars also not previously visible. From a site posterior and superior to the tympanae appeared two similarly coloured but slightly narrower stripes which diverged slightly in the middle of the back, and then passed beyond the termination of the vertebral stripe, and parallel to it, to a point situated approximately one third of the way down the tail where they merged with the ground colouration.

Since the colour of A. adelaidensis varies so much from one individual to another, the extremes of the range may be retained after preservation of specimens for museum collections, and thus be a contributory cause to the present confusion of the status of the species.

Stirling and Zietz (1893) found the measurements of the larger of two specimens collected between Queen Victoria Spring and Fraser Range to be: body 50 mm.; tail 70 mm. -- total length 120 mm. Waite (1929) recorded a specimen measuring: body 48 mm.; tail 78 mm. -= total length 126 mm. Since the Nullarbor material included several specimens exceeding these in length, it is suggested that the former had not reached maximum size when captured.

A form distributed in S.W. Australia and observed by the writer on the

Nullarbor Plain a few miles east of Deakin, lacks the lateral spines at the base of the tail.

There exists a very real need for a revision of all species at present with the genus *Amphibolurus*, for only after such a measure can the distribution of *A. adelaidensis* be correctly determined.

(b) *Factors limiting the variety of potential prey*

Before discussing the diet of *A. adelaidensis*, it is advisable to consider the environmental factors, especially seasonal and climatic conditions, which determine the variety and population density of those insects which can, by virtue of their size, be regarded as potential prey.

The region where the lizards were captured is one of the most barren parts of the Nullarbor Plain. Live vegetation consisted of occasional xerophytic plants which, because of their high salt concentration, are unsuitable host plants to any but a few species of specialised insects.

The presence of occasional dense swarms of flies, however, provided a reminder that the region is not entirely lacking in organic matter.

The temperature at the time of most of the captures was $90°-110°$ F., whilst Northerly winds were maintained, which is of interest since it has been established that wind inhibits the flight of insects, particularly flies.

It may be presumed that the conditions on the Nullarbor Plain are most suitable, so far as lepidopterous insects are concerned, for those species capable of completing their metamorphosis in the short period after the rainy season when the vegetation is most prolific, and then adapt themselves to arid conditions.

A seasonal variation in the insect population will be reflected by stomach contents of insectivorous lizards, if they are indiscriminate in their feeding habits.

(c) *The feeding mechanism*

Knowledge of the powers of sight and the stimuli inducing ingestion in the Sauria and Batrachia is improperly known, and certainly varies between different species.

If the feeding mechanism is an automatic one induced solely by the movement of a small object within the animal's range of vision, then the creature must be an indiscriminate feeder.

Such a case is well illustrated by the example of large frogs of the family Ranidae, which were observed by the writer to inhabit a reservoir at Maltepe, near Istanbul, Turkey, which automatically ingested any small object thrown near to them, including stones.

The other extreme is where animals are capable of distinguishing between closely allied insect species, as is the case with *Moloch horridus* discussed earlier. In this instance sight probably played very little part in the discrimination, for the species selected was characterised by a strong smell (obnoxious to the human being), which was absent in the species rejected.

As has been seen in Fig. 2, the Hymenoptera was the order of insect most frequently ingested by *A. adelaidensis*, and it is most difficult to decide whether the species discriminated between different types of prey, or whether availability is the all important factor. Ants were undoubtedly the insects most frequently seen, and would presumably form a high proportion of the total insect population were an ecological survey undertaken.

A consideration of many papers on various animals led McAtee (1932) to conclude that availability is the all important factor governing the food items

ingested. This can hardly be considered a complete answer in itself, for species of similar size and habits in the same region (Cott. 1957) show marked differences in the prey selected. Another point previously almost completely ignored is that individuals within a species captured under identical conditions differ widely in prey selected and demonstrated, even in the Batrachia, apparent individualistic tendencies (Tyler, 1958).

The present paper records the diet of *A. adelaidensis*, which foraging for food is probably a discriminate feeder, but its limitations reveals the need for new field techniques for dietary studies upon small animals.

## ACKNOWLEDGMENTS

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# DETERMINATION OF THE ABSOLUTE GRAVITY VALUES ON THE SUMMITS OF A NUMBER OF PROMINENT HILLS IN THE MOUNT LOFTY RANGES*

*BY* I. A. MUMME

## Summary

Gravity observations have been carried out on a number of prominent hills in the Mount Lofty Ranges.

# DETERMINATION OF THE ABSOLUTE GRAVITY VALUES ON THE SUMMITS OF A NUMBER OF PROMINENT HILLS IN THE MOUNT LOFTY RANGES*

By I. A. Mumme

[Read 8 October 1959]

## SUMMARY

Gravity observations have been carried out on a number of prominent hills in the Mount Lofty Ranges.

## INTRODUCTION

The gravity measurements were conducted with a Carter Y2 gravimeter and the gravity values determined in the Mount Lofty Ranges are based on an absolute gravity value of 979·7232 gals. at the gravity base station in the New Observatory (in the grounds of the University of Adelaide).

In determining the absolute gravity values on the summits of the hills investigated, it was necessary to establish a number of intermediate gravity stations.

The observed gravity values for the gravity stations on the summits of the hills were reduced by applying the following corrections:

(1) Elevation correction,
(2) Topographic correction.

Bouguer Anomalies were computed by subtracting the theoretical gravity values for the gravity stations from their reduced gravity values.

## PREVIOUS GEOPHYSICAL WORK

No previous programme of gravity measurements on the summits of hills have been conducted in South Australia.

However, a number of gravity determinations have been carried out on the summit of Mount Lofty with gravimeters.

E. McCarthy, of the Bureau of Mineral Resources, determined the gravity interval between the Old Observatory (West Terrace, Adelaide) and the Mount Lofty Summit gravity station with a B.M.R. gravimeter during 1949.

He obtained a value of 979·5893 gals. for Mount Lofty, which is based on a value of 979·7219 gals. at the Old Observatory.

From June, 1949, to January, 1952, Muckenfuss, on behalf of Wood's Hole Oceanographic Institute, carried out world-wide gravimeter observations with a geodetic Worden gravimeter.

He determined a value of 979·7258 gals. for gravity at the New Observatory in the University of Adelaide, and a value of 979·5932 gals. for the Mount Lofty gravity stations.

The writer obtained a value of 979·5906 gals. for the Mount Lofty gravity station, which is based on a value of 979·7232 gals. for the New Observatory gravity station using a Worden gravimeter.

A gravity interval identical with that obtained by Muckenfuss was determined.

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I. A. MUMME

TABLE (1) OBSERVATIONS ON GRAVITY AT
SUMMIT STATIONS IN THE MOUNT LOFTY RANGES

| Gravity Station | Observed Gravity | Height above sea-level | Elevation Correction | Topographic Correction | Reduced Gravity | Latitude | Longitude | Theoretical Gravity | Bouguer Anomaly |
|---|---|---|---|---|---|---|---|---|---|
| | gals. | feet | mgals. | mgals. | gals. | | | gals. | gals. |
| New Observatory | 979·7232 | | | | | | | | |
| Mt. Lofty Summit | 979·5906 | 2,334 | 140·0 | 3·14 | 979·7337 | 34°58·3' | 138°42·5' | 979·7432 | −0·0095 |
| Mt Kitchener | 979·5839 | 1,965 | 117·9 | 2·76 | 979·7046 | 34°34·8' | 138°59·3' | 979·7101 | −0·0055 |
| Pewsey Vale Peak | 979·5748 | 2,064 | 123·8 | 3·41 | 979·7020 | 34°37·6' | 138°57·6' | 979·7140 | −0·0120 |
| Mt. Crawford | 979·6115 | 1,844 | 110·6 | 2·56 | 979·7247 | 34°42·0' | 138°57·9' | 979·7202 | +0·0045 |
| Belvidere | 979·6122 | 1,284 | 77·0 | 1·54 | 979·6907 | 34°25·7' | 138°54·2' | 979·6973 | 0·0066 |
| Patterson's Hill | 979·6355 | 984 | 59·0 | 0·21 | 979·6947 | 34°29·1' | 138°54·3' | 979·7021 | −0·0074 |
| Kelly Hill | 979·5997 | 1,121 | 67·3 | 0·34 | 979·6673 | 34°15·1' | 138°40·6' | 979·6825 | 0·0152 |
| Gilbert Hill | 979·6163 | 950 | 57·0 | 0·16 | 979·6735 | 34°17·7' | 138°41·4' | 979·6861 | −0·0126 |
| Light Hill | 979·5877 | 1,494 | 89·6 | 0·28 | 979·6776 | 34°18·1' | 138°50·3' | 979·6867 | −0·0091 |

## METHODS USED

The Carter Y2 gravimeter was calibrated by measuring the dial interval (allowing for instrumental drift) between the New Observatory and the Mount Lofty gravity station, assuming a gravity interval of 0·1326 gals., and a factor of 0·0809 milligals per division was obtained for the sensitivity factor. Gravity differences between the New Observatory gravity station and the summits of the hills investigated, were obtained by establishing a number of intermediate gravity stations and measuring the gravity intervals between successive stations and thus obtaining the total gravity interval between the New Observatory and the summit of a particular hill in the Range.

Repeat readings were taken in measuring the gravity intervals and curves drawn up to allow for instrumental drift.

## REDUCTION OF RESULTS

The observed gravity values for the gravity stations located on the summits of the hills were reduced to mean-sea-level by applying the following corrections.

(1) *Elevation Correction*

This correction is composed of two components, namely the Free-Air correction and the Bouguer correction.

The Free-Air correction is a constant correction per unit change elevation and is equal to 0·0946 milligals per foot.

The Bouguer correction is to allow for the gravitational effect of the rock material between the gravity station and the datum level (mean sea-level), assuming that the material consists of an infinite plate of rock.

The correction is $0·0127d$ milligals per vertical foot, where $d$ is the density of the rock material between the gravity station and mean sea-level.

(2) *Topographic Correction,*

Due to the hilly nature of the terrain surrounding the gravity station, a topographic correction had to be applied.

A graticule devised by S. Hammer was used.

## THEORETICAL GRAVITY VALUES

The 1930 International Gravity Formula was used in obtaining the theoretical gravity values for the gravity stations at mean sea-level, namely:

$$Go = 978·049 \ (1 + 0·0052884 \sin^2\phi - 0·0000059 \sin^2 2\phi) \text{ gals.}$$

Bouguer Anomalies of the gravity stations were calculated by subtracting theoretical gravity values for the gravity stations from the reduced gravity values obtained by applying Elevation corrections and topographic corrections.

The observations, corrections and theoretical values are brought together in Table (1).

# RATTUS GREYI GRAY AND ITS DERIVATIVES

*BY H. H. FINLAYSON*

**Summary**

# RATTUS GREYI GRAY AND ITS DERIVATIVES

By H. H. Finlayson

[Read 8 October 1959]

3 Plates and Text Fig. 1

## CONTENTS

## 1. INTRODUCTION

The original form of this distinctive Australian rat was described by J. E. Gray (1841) from two cotypes sent to London from South Australia. Captain G. Grey, who is traditionally credited with being their collector, visited South Australia unofficially in 1840, before his assumption of the governorship of the province in the following year, and it has been generally accepted that the locality "vicinity of Adelaide" quoted in the appendix on mammals in his Journal, is to be accepted literally in localizing the type. While the circumstances of this early Colonial time might be thought to render this probable enough it cannot be regarded as definitely established and some evidence to the contrary is later presented (*infra*).

No further systematic work was done on the species for more than 80 years, during which time several "records" of it were later shown (or have come to be regarded) as erroneous and based on misidentifications (Collett, 1887; Ogilby, 1892; Waite, 1896). It is somewhat remarkable that Gould who also travelled widely in the State did not recognise the distinctness of "*Mus greyi*" of Gray, but relegated that name to the synonymy of *Mus gouldi* Waterhouse (now referred to *Thetomys*); and later (1858) in describing *R. assimilis* from New South Wales, which is so close to *R. greyi* as to be considered conspecific by

some authors, he did not alter that opinion. In 1921, O. Thomas obtained further material from Mt. Compass through the good offices of Professor Wood Jones, then working in Adelaide, and after reviewing the series referred to *R. greyi* in the British Museum, concluded that it was not homogeneous, and designated one of the former cotypes as a lectotype to represent Gray's species. This specimen (B.M. 41, 1266) is stated by Tate (1951, 329) to be of the "Gould Collection". At the same time, Thomas (*op. cit.*) described *Rattus culmorum austrinus* from a specimen collected by J. B. Harvey, and donated to the Zoological Society of London in 1841. Harvey collected both on Kangaroo Island and at Port Lincoln on Eyre Peninsula and the place of origin of the type of *austrinus* is also quite uncertain, Thomas (1921) and Tate (1951) accepting Kangaroo Island, and Iredale and Troughton (1934) and Ellerman (1941), Pt. Lincoln. This dispute would have no relevance here were it not for the fact that Tate (1951) has been brought to the conclusion that *austrinus* is a form of *R. greyi* and not of *R. culmorum*. Troughton (1920) recorded the persistence of the species (under the pseudonym *R. assimilis*) on both Kangaroo Island and Eyre Peninsula.

A second insular representative was discovered by Wood Jones on Pearson Isles in the Investigator Group of the Eyre Peninsula coast, and this was described by Thomas (1923) as a full species, *Rattus murrayi*, but now more generally regarded as *R. greyi murrayi*. Wood Jones (1924, 1925) gave an excellent general account of both the mainland and island forms and provided the first illustrations of the species. In 1936 Brazenor separated a western Victorian population from the typical form under the name *R. g. ravus*; but this being preoccupied by *Epimys ravus* (= *Rattus ravus*) of Robinson and Kloss was replaced by *peccatus* by Troughton (1937); Tate (1940) independently noted the preoccupation of *ravus* and suggested *brazenori* as a substitute. These described forms have since been noted and discussed in monographic works on muridae by Ellerman (1940-1949) and Tate, 1951. In spite of this considerable body of work it cannot be said that *R. greyi* is a well understood species. Not only the vagueness in the provenance of early types, but still more, the tendency to limit the basis of differential characters to the barest conventions of museum systematics, renders the subspecific identification of material from descriptions, a hazardous proceeding.

The local interest of *R. greyi* derives largely from its insular representatives which are frequently the only mammals on the islets of the continental shelf which can be obtained in numbers, and which if fully studied might give valuable information on the post-Pleistocene history of this area. The immediate origin of the present paper has been the necessity of assessing the degree of differentiation which has been attained by an island population as compared with one from the mainland, and in such work holotypes, however well described, are of limited service if unaccompanied by data on topotype series which can supply the key to the range of variation normal to the form they represent. The correspondence or divergence of individual specimens of closely related and intergrading forms may be largely a matter of chance, but population trends, as shown by the frequency with which characters recur, is likely to be much more significant of affinity.

Although several considerable series of *R. greyi* are stated to exist in collections, both in this country and overseas, no adequate analysis of their characters is available for such a purpose as I have indicated. Between 1936 and 1939 during the course of field work by the writer in the Fleurieu Peninsula, chiefly upon the associated species *R. lutreola*, a considerable series of *R. greyi* was obtained as a by-product. This material, personally collected over a restricted

area and fully authenticated with field data, lends itself well in making good this deficiency, which forms the chief content of the sequel. The series is then used as a standard in a re-examination of other groups both insular and mainland, which are available here, and in addition, the distribution, status, and habits of the species are briefly discussed and some details given of its behaviour in captivity.

## DISTRIBUTION AND HABITS

The present distribution of the species, as far as it is known, involves a narrow subcoastal strip extending from the Portland district of western Victoria to the southern portion of Eyre Peninsula in South Australia and some of its off-lying islands, and is thus almost entirely within the territory of the latter State. Its eastern extension in Victoria, however, may be considerably greater than is supposed, as it tends to be masked by the overlap with the very similar *R. assimilis*, the most westerly record of which appears to be at Beech Forest in the Otway Peninsula of Victoria.

The range thus interpreted is one of the most restricted for Australian rats, but if Tate's suggestion (1951) is adopted of considering *R. greyi* as a subspecific south-western off-shoot of *R. assimilis*, the combined range is then probably the most extensive, the forms *R. a. coracius* extending to north Queensland and *R. a. manicatus* to the Arafura coast of the Northern Territory. The absence, so far as known, of any representative of the species group in Tasmania and the frequency of its occurrence on the islands of the South Australian coast, is a significant point in its distribution. Shortridge (1936) claimed *R. greyi* (as distinct from *R. fuscipes*) as a member of the Western Australian fauna, but this is not confirmed by Glauert (1950). Tate (*op. cit.*) suggests that such an extension was established during the last pluvial phase of the Pleistocene and has lapsed during subsequent dry times, but he was inclined to underrate the arid tolerance of modern *R. greyi* as shown, for example, by the dune colonies of Eyre Peninsula and some of its islands, and it may yet be found to extend much further along the south coast in this direction also.

In South Australia at the present time it is well established in the southern portion of the Mt. Lofty Range and on Kangaroo, Greenly, Pearsons, Nth. Neptune, and Gambier islands and probably on several other islets off the coast. It occurs much more sparsely in the lower South-eastern District and persists also in small numbers along the coastal portion of the Adelaide-Wakefield Plain and in the southern portion of Eyre Peninsula. The early obliteration both of fauna and vegetative cover by farming operations in large portions of lower South Australia, necessarily leads to a patchy, discontinuous distribution common to most local mammals at present, but how far this was true of the pre-European era and to what extent the present occupied areas were formerly linked, is largely conjectural. Its survival north of Adelaide, in sheltered, unutilized spots, such as the mangrove belts, suggests that it may formerly have occupied many of the timbered portions of the wheat lands of the Lower North and of Yorke Peninsula. It is absent from the major expanses of the Mallee, and sub-fossil records do not appreciably extend the existing distribution.

Today, in the hill tracts south of Adelaide, wherever sufficient cover has been left for its needs, it holds out in small numbers and seems able to survive the attentions of both the fox and domestic cat, and is one of the very few native mammals which are at all likely to be taken here by random trapping. Twenty years ago, before the use of trace elements led to a phenomenal increase of pasture and sheep breeding, the portion of the Fleurieu Peninsula south of the

watershed and including the valleys of the creeks between the Waitpinga in the east and the Tapanappa in the west, was an almost virgin wilderness and *R. greyi* was in very large numbers here and almost ubiquitous. It could be trapped with almost equal certainty on dry laterite ridges under stands of stringy bark timber (*Eucalyptus obliqua* and *E. baxteri*) and dwarf eucalypt scrubs or in the tangled jungly growth along the swampy heads of creeks; the former, however, and hill slopes with moderate cover of bracken and xanthorrhea were the more characteristic stations. In this area it had no marsupial competitors and few effective predators and the periodic bush fires which swept the creek valleys from the divide down to the sea were the only cause of large scale mortality. From these disasters, however, it made rapid recoveries and reoccupied the burnt country with remarkable speed. Its relations with *R. lutreola* which also has a firm hold on this country will be more particularly discussed elsewhere, but it may be remarked that it is a much more wide ranging and adaptable animal than the latter and only comes into competition with it in the immediate vicinity of the restricted *lutreola* colonies which are usually in damp areas near the creek beds or in wet swamps. Unlike the west Victorian and Kangaroo Island populations which make considerable living burrows in suitable soils the local form of the Fleurieu Peninsula does not normally burrow, but shelters in or under fallen logs and in matted banks of grass and sedges and dried fern. Even where very plentiful it *is* quite inconspicuous, leaving no well-defined runways and being seldom seen by day.

Some information on the feeding habits has been obtained by the examination of stomach contents of considerable numbers from the Fleurieu Peninsula; this consists most frequently of a dark coloured, finely ground pulp in which seed case fragments form the chief recognisable constituent. Incineration of the dried mass yields an ash rich in sand which gives colour to the view that subterranean materials are largely used for food. This had been inferred independently from the frequency with which the rat had been trapped on burnt clearings under timber where the soil was much scarred by fresh, shallow excavations. About one-half the stomachs contained appreciable quantities of insect material representing both Coleoptera and Orthoptera, and in two cases a fleshy mass derived, at least in part, from an Amphibian. No trace of green vegetation could be detected. The available evidence, therefore, suggests that in this district at least, seeds, roots and tubers are the chief elements of the diet, with a not unimportant intake of insects and small vertebrates. It is very easily trapped with a variety of baits of which bread, fat and sliced apple were found about equally effective.

The stomach frequently carries a heavy infestation of a nematode, identified by Mrs. I. M. Thomas as a *Physaloptera* species, and several unidentified ectoparasites occur, of which the most important quantitatively is a *Laelaps* species.

As regards reproduction, the data is scanty and the evidence mostly negative as the greater part of the Fleurieu Peninsula series was obtained at times when reproduction was largely suspended. However, by combining such information as it yields, both in the field and in captivity, with that from other South Australian mainland localities and from Greenly and Gambier Islands and western Victoria, it may be seen that, in the male, testes first undergo a sudden enlargement and become scrotal in site in July and August and may be found so till the following February; and that in the female activity in the form of observed littering of wild caught rats in captivity, and lactation and pregnancy in the wild, extend from September till February. While the evidence from any one locality is inadequate for a positive statement, the combined data might be

taken as indicating that the overall reproductive pattern for the species is one of activity from late winter or early spring to late summer (July-February) and that there is a period of quiescence in autumn and early winter (March-June). Vulval occlusion is absent in the Fleurieu Peninsula series and in other mainland material has been noted in one example only; a subadult from the Meadows Creek area, slightly north of the main series, in April. It is more frequent in a Greenly Island collection (*infra*). The number of litters per year is not ascertained. In the single littering observed in captivity four young were produced, but in western Victoria, six full-term uterine embryos were observed in two cases.

Numbers of *R. greyi* taken in the Fleurieu Peninsula were kept in captivity for varying periods under conditions similar to those described for *Pseudomys* (*Gyomys*) *apodemoides* in my paper of 1944. On a diet of mixed grain, potatoes and hard fruit, which was always present in the cages in excess of requirements, and supplemented by a small ration of egg, honey, powdered milk and fat bacon, it appeared to thrive and produced and reared young. Water was drunk sparingly when supplied, but is not essential, and two groups, one captive born and one wild, lived through a hot summer without it.

In general, it proved to be a vigorous, restless and aggressive little creature. The males made almost ceaseless attempts to escape and frequently succeeded by gnawing holes in the wire netting, but the escapees made little use of their freedom, seemed nonplussed by their enlarged surroundings and were usually easily retrapped in the vicinity of the cages. I cannot confirm Wood Jones' (1925) description of its "gentle" character. Its failure to bite when handled (which is not invariable) seems to be due to a paralysis of fear rather than to tolerance, and though it may not move away when touched, it frequently trembles, its tail beats an involuntary tattoo and its eyes bulge in their sockets. Impressions of temperament no doubt depend on the social balance of the communities observed. The groups which I have watched always contained an excess of males and under these conditions it appears in a very different light. Its libido during the season is quite insatiable and under stress of sexual competition it wages relentless war on all rivals real or potential and either kills or incapacitates them or enforces a recognition of its dominance. New additions to the colony were always treated with hostility though they all came from a very restricted area of the Peninsula. On at least one occasion house mice straying into the cage were killed and eaten.

Natural vegetation from the site of capture was used to carpet the cages and hollow logs and nest boxes were provided for shelters; these were generally occupied by pairs, but solitary males often made grass nests for themselves in the corners, either of an open cup-shaped form (Pl. 2. Fig. A) or a much larger domed structure, with an entrance near the base (Pl. 2. Fig. B). Much time and labour were expended in constructing these nests, which are not just random heaps of material, but were made by interweaving selected stems. They were demolished and rebuilt at frequent intervals, and nest building is evidently an important natural industry of the species. Transference of a group to a new cage was always followed by a tremendous burst of activity, all crannies and furnishings being examined in minute detail and moved if possible. At such times it ventured out freely in daylight, but ordinarily its activities were strictly nocturnal. It gave no evidence of any special climbing ability, and though it clambered about the netting on occasion, it made no use of the perches provided. The voice is much in evidence in young animals, but adults are rather silent, except when fighting or threatened, when they squeal harshly. The ectoparasite *Laelaps* sp. which is almost always normally present

in the wild, tends to increase unduly in captivity but may be checked by frequently dusting with pyrethrum.

The following serial notes cover some points of general interest in the development of a litter in captivity. The female, having left her mate and begun to make a nest separately, was transferred alone to a smaller cage, where four young were born next day (September 8) at unascertained intervals. They were uniformly pink on all surfaces and smooth and very vocal, using a shrill birdlike call when left in the cold by the mother. If disturbed at the nest she frequently jumped out, dragging some of the young with her, but they did not adhere firmly to the nipples. The female had but four of the ten mammae functioning — two inguinals and two pectorals.

*At 5 days*: The young were removed from the nest, examined and weighed, using a stoppered weighing bottle; weight 5 g. They were now perceptibly darker above than below and wrinkled; the mysticial vibrissae quite apparent and all white. When returned to the nest, the young were immediately flung out by the mother and rolled to and fro on the grass of the floor with her hands for a minute or more. She then took them in her mouth and carefully replaced them in the nest. This decontamination rite was frequently, but not invariably, carried out on future occasions of handling.

*At 9 days*: Dorsum now much darker than ventrum and completely clothed in a fine lead coloured down which is tinged with yellow on nape. The nestlings were vigorous but not capable of locomotion.

*At 12 days*: All young weighed 8 g.; pelage considerably advanced, the yellow areas extending nearly to the rump and on the outer aspect of the forelimb a conspicuous patch of lead coloured underfur has appeared. Though still blind they could now scramble slowly over a bench. The three males were recognisable by minute paired spots of pigmented epidermis on the scrotal sites.

*At 16 days*: Pelage now markedly thicker, but of the same length and covering all the trunk and limbs but not the ears nor tail. The young were able to remain balanced on all four limbs and to walk an inch or two.

*At 19 days*: Weight 10 g.; furring of body and appendages complete; on the tail both scutation and hairs were apparent and its dorsal surface distinctly darker than below; dorsum of the pes haired with pure white on the toes only, that on the metatarsal area being slightly darkened at base. The soles of the pes were now darkened to a pale slate colour, but the palms of the manus, pink.

*At 4 weeks*: Eyes opened on the 22nd day. When removed from the nest the young jumped freely and ran and climbed about the cage and when handled made determined attempts to bite; the lower incisors were still white.

*At 5 weeks*: ♂ 13 g.; ♂ 11 g.; ♂ 13 g.; ♀ 13 g. The pigmented scrotal sites are still conspicuous and in the female there is no vulval occlusion. Though they were not seen to voluntarily leave the nest they undoubtedly do so at night and are taking solid food freely. Both upper and lower incisors were now yellow, but the former much darker. On the 34th day one of the 13 g. males was found dead; head and body, 73; tail, 60; pes, 20; ear, 15·5 × 10; rhinarium to eye, 12; eye to ear, 12; skull greatest length, 25·6. The third molar had not yet erupted.

*At 6 weeks*: Another male found dead and partly eaten; the survivors weighed ♂ 14 g.; ♀ 16 g.

*At 9 weeks*: ♂ 23 g.; ♀ 33 g. The young had not been under close observation since last weighing and the remarkable disparity in size was quite unexpected; the male appeared to be entirely normal and healthy and active but was much less bulky than the female. Areas of exposed epidermis were still relatively unpigmented and when exposed to sunlight or handled, the light

coloured parts of manus, tail, pes and rhinarium, but not the ears, became deep pink. They were still comparatively leggy and awkward; they climbed about the netting more than adults but showed no agility at it. The male, having given evidence of rut, the dam was removed from the cage.

*At* 10 *weeks*: ♂ 30 g.; ♀ 38 g. At this time the pair made a grass nest exactly as fabricated by the wild born rats, and shared it. Regular observation and weighing had to be abandoned at this point, but in the next six months the young weathered their first summer successfully on the standard diet and without water. They were somewhat tamer than wild caught specimens, but the male always attempted to bite when handled. The pelage was now generally similar to that of the duller coloured adults, but less dense and glossy, and with fewer guard hairs and correspondingly reduced grizzle.

*At* 37 *weeks*: The female was found dead, having delivered four premature young; head and body, 136; tail, 130; pes 27·5; ear, 19 × 11·5; weight 80 g.; these dimensions are still somewhat below the approximate means of adult wild females, as selected by molar wear in the sequel (*infra*).

The surviving male was mixed in with a wild caught group of both sexes, but after resisting steady persecution for six months with varying success, he was removed to a cage of his own where he outlived the entire colony, dying during a heat wave on January 13, 1939, when day temperatures rose to 113 deg. in the shade; head and body, 151; tail, incomplete; pes, 27; ear, 20 × 12; wt., 145 g.; skull greatest length, 35·1. These values for head and body and weight exceed the approximate means of the adults of the wild caught series, but some others, notably the pes, are much lower, though all fall within the range except the weight. This exceeds the maximum for the wild caught group by 30 per cent. and was due to excessive fat. The skull length barely attains the minimum for the wild "adult" group subsequently measured (*infra*).

The death of this male at two years four months of age was almost certainly premature and probably due to heat apoplexy. Though the skull characters may have been modified by captivity, they do not suggest an aged condition, when compared with the oldest of the wild series. A life span for the species in nature of three or four years seems probable.

## 2. DEFINITION OF A STANDARD POPULATION OF R. *GREYI GREYI* GRAY, 1841

The material examined below, which is later used as a standard series for assessing the status of other populations, was taken near the heads of the Callawonga, First, Boat Harbour, Tapanappa and Blackfellows Creeks in the Fleurieu Peninsula at the southern extremity of the Mt. Lofty Range. That it may be accepted as representative of the primary subspecies is indicated (within the limitations inherent in such comparisons) by the consonance of the lectotype with the range of variation now described and by the specific statement of Thomas (1921), that Wood Jones' donation from Mt. Compass was in agreement with the lectotype; this locality being but a few miles north in the ranges and presenting very similar ecological conditions to those of the drainage of the creeks named.

A strict interpretation of the term "vicinity of Adelaide" might put the type locality on the coastal Adelaide-Wakefield plain, which has some claim to be considered as a distinct natural region, differing from the highlands fifty miles to the south, which yielded the present material, in lower rainfall, higher mean

temperatures and, of course, in soils and vegetation. As will be shown later, the few specimens which are certainly known from this plain, show slight differences, and give colour to the view that the type locality lies in the Hills district to the south.

The Fleurieu series comprises 45 individuals representing an adequate range of sexual, seasonal and age phases; approximately one half of it is in the form of skins and skulls, with the remainder alcohol preserved. The sex ratio is 23 ♂ : 22 ♀.

## (ii) EXTERNAL CHARACTERS

Size small; the phase of the species under consideration being one of the smallest of Australian rats. Limbs and appendages slender and delicate and the body build light and gracile, the dumpiness, which has been remarked (Wood Jones, 1925), being due to posterior lengthening of pelage rather than to a somatic character. The head (Pl. 3, Fig. A) is relatively large in comparison to body length and general bulk and has a well arched profile and but medium rostral development. The ear is thin in substance, bluntly rounded and carried conspicuously free from the head fur. The eye is large and prominent, and under emotional stress is capable of a remarkable degree of protrusion.

The *facial vibrissae* are relatively very strongly developed in *R. greyi*; all sets are well represented and the mysticials, genals and supraorbitals in particular are very long though slender bristles with extremely attenuated tips. As they are much subject to shortening by abrasion and breaking, the lengths quoted have been taken from a selected group of apparently undamaged examples, and except for the mysticials which alone have been used comparatively, the maximum observed length only is quoted. The counts have been made on fully furred examples, which in the case of the smaller bristles, present more difficulty than in earlier nude or part furred stages, so that these numbers are subject to correction.

In the *mysticial* set, the shorter, anterior, members are white for the greater part of their length, the remainder blackish brown with white tips; length in adults ranges from 42-53 with an approximate mean of 46·7; the three longest examples were supplied by males, but the mean for females is almost as high (46·0 cf. 47·4). The *genal* set is most frequently reduced to a single bristle, but rarely two of almost the same length and set very closely together, may be present; maximum 29 mm. *Supraorbitals* apparently normally two, though only a single bristle survives in some and a third very small member may be present in others; these, with the genals, have the same colour distribution as the longer mysticials; maximum 32 mm. A *postoral* papilla is strongly and consistently developed at a site about 6 mm. behind the oral canthus and supports three bristles, the longest (to 14 mm.) being dark at base and white tipped and the other two entirely white. The *submentals* are often difficult to delimit as a median group since numerous irregularly disposed bristles extend from the midline across to the angle of the mouth, where they are often longer than on the name site; the longest noted was 7 mm. and all are white to base. The *intermmals* are also difficult to define in furred material owing to a tendency of the median papilla to break up into two or even three separate papillae, each provided with sensory hairs so that a total of six or more may be present; the largest complement noted on the median site was four, and the maximum length 14 mm.; these, like the submentals, are all white to the base.

The *manus* (Pl. 3, Figs. C and D) is slender and narrow, with a length from the base of the metacarpal pads to the summit of the apical pads (excluding

claw) ranging in fully adult examples from 13·0-14·0 mm. and the breadth transversely across the palm from the base of the 2nd digit from 4·5-5·0 mm. yielding an approximate mean breadth/length ratio of 0·37; the 3rd digit to 5·5 mm. and its claw to 2·5 mm. as maxima. The digital formula (length only) is $3 > 4 > 2 > 5 > 1$ but $4 > 3$ occurs rarely, and the 4th digit is always the stoutest. The claws are moderately developed, yellow horn coloured and with a free projection about equal to the apical pads and lightly fringed with bristles. The pollex is relatively well developed and its nail is large and conspicuous dorsally. The general colour of the palmar surface in life is pink; the central portions are deeply creased but not punctate nor granular. The grooves of the palmar surface of the digits are deeply incised and the 4-5 semi-annular ridges which they enclose are prominent and entire distally, but the proximal two are commonly broken up into scales, in a more decided fashion than is usual in Australian *Rattus*.

The *palmar pads* are smooth and rounded in outline but are relatively large and with bold relief; the surfaces are feebly striate. The interdigitals are mounted on prominent folds of integument which in available illustrations (Wood Jones (1925), Brazenor (1936) *op. cit.*) are not always distinguished from the pads themselves, so that very different conditions appear to be attributed to the species. The metacarpals vary considerably in shape and area and have extensions on to the lateral aspects of the manus, which complicate the overall appraisal under these heads. The outer metacarpal (hypothenar) is always the longer and extends lower towards the carpus and in palmar aspect is usually twice as long as broad, and a pointed oval in shape. The inner metacarpal is shorter and broader and is sometimes equal and rarely greater in area than the outer; its palmar portion is roughly an inverted U or bell shape, with a depression between the arms and an accessory fold on the lateral aspect towards the pollex, separated from the main portion by a distal notch. The interdigitals are somewhat more constant, the most frequent shape being an inverted broad piriform for the median pad and inverted cardiform for the 1st and 3rd. The 3rd interdigital has a small circular satellite pad at its postero-external angle with a frequency of about 90 per cent., which, however, may be reduced to a dependant heel or disappear altogether. In point of area the prevailing pad formula is: outer metacarpal > inner metacarpal > 2nd interdigital > 3rd > 1st[1], but as shown above the metacarpals may be equal, or the inner the larger.

Neither median antebrachial nor anconeal vibrissae were traced on the forelimb in the available material; the ulnar carpals are 4-5 in number, arranged in two groups, and are pure white to base with the longest of the set reaching 13 mm. as a maximum.

The *pes*, relative to head and body length, is one of the longest amongst Australian species of *Rattus*, with an approximate mean value in adults of 19·7 per cent. of the head and body, and also one of the narrowest, the ratio of breadth across the sole from the base of the 1st digit, to the length, averaging about 0·22. It tapers gently for most of its length and has a well constricted calcaneal portion; the 3rd digit reaches 7 mm., its claw 3·5 mm. and the hallux 4 mm., as maxima. The digital formula is as in the manus and the 4th digit again usually the stoutest; the claws sharp and delicate, coloured as in the manus, but with longer fringing bristles which may exceed them by their own length. Digital rings increased to 6 on the 2nd, 3rd and 4th and all except the distal member divided into 2 (or basally into 3) large scales. The colour

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[1] The 2nd of the primitive pentadactyl manus.

of the sole is pale pink with the central portions sometimes darkened with an infusion of slate, which, however, does not extend to the pads.

The *plantar pads* are strongly developed and more definitely striate than in the manus. The inner metatarsal in this series is notable in being broader than usual and generally lacks the long, drawn-out, comma-shaped tail, common in the genus; in shape it is an irregular oval narrowing proximally but with its maximum breadth often more than half its length. The outer metatarsal is broad oval or nearly round and only one-quarter or less of the area of the inner. The median interdigitals are regularly piriform and the laterals inverted cardiform; the 1st with a slight depression towards the heel, and the 4th with a distinct separate satellite pad at the postero-external angle in 50 per cent. of cases only; in the remainder, it may be represented by an accessory fold or heel or be entirely absent (20 per cent.); much more rarely a heel or satellite may appear at the base of the 1st interdigital. In adults, the most frequent size relation is: inner metatarsal > 3rd interdigital > or = 2nd > 4th > 1st > outer metatarsal; this accounts for 85 per cent. of cases, but it is characteristic of the species that the lateral interdigitals are large with respect to the median and a condition of subequality between all four may be reached; in two cases the median inter-digitals are larger than the inner metatarsal.

Calcaneal vibrissae were not traced.

The *tail* is slender and gently tapered, with attenuated apex and no ter-minal expansion. The relation of its length to that of the head and body ranges from 85-110 per cent. with an approximate mean of 94·3 per cent. In the group of seven species which have been chiefly used in these comparisons and com-prising *R. greyi, assimilis, lutreola, villosissimus, colletti, norvegicus,* and *R. alexandrinus,* this mean is exceeded by the latter alone. In the entire series of *R. greyi* from the Fleurieu Peninsula, the length of tail equals or exceeds that of the head and body in about 24 per cent. of cases and the distribution of the frequency of this relation shows only slight differences between ♂ and ♀ (26 cf. 21 per cent.) and adults and subadults (22 cf. 25 per cent.), so that the variation in this feature is very largely an individual one. Scale counts were not made upon animals in the field, but as the range observed in alcohol pre-served material and in filled skins is identical, it is probable that the results obtained are characteristic of this form. The middorsal count in adults ranges from 12-14 per cm., 13 scales having the highest frequency (54 per cent.) and 14, 38 per cent. Proximally, the dorsal count averages slightly less, while dis-tally it may rise as high as 21 per cm. at the apex. In subadult and immature phases the count is decidedly higher, the middorsal number ranging from 13-15 per cm. with frequencies of 44 per cent. for 15 scales, 31 per cent. for 14 and 25 per cent. for 13. The number of hairs per scale is normally three, but shows considerable irregularity dorsally, especially towards the base, where it may vary from one to three. The length of tail hairs is from 2-2·5 scales middorsally and increases distally. The tail is decidedly darker above than below in a large majority of specimens, both scales and hairing contributing to the effect, but the degree of the difference varies widely and it may be almost as pale above as below, but is never darker below. Light coloured epidermal markings, possibly traumatic in origin, are sometimes present and rarely as much as 20 mm. at the apex may be entirely white, both as to epidermis and hair.

The *mammary formula* in lactating females examined is 2-3 = 10, but in subadults or quiescent adults, the nipples are very completely retracted and in many of these the pectoral and sometimes the thoracic as well, could not be traced by ordinary macroscopic examination under a lens, but whether they are completely suppressed as implied by Wood Jones (*op. cit.*) remains to be

shown. As mentioned above, in a female lactating in captivity for four young, only four of the ten were functioning; two pectorals and two abdomino-inguinals. The pectoral and thoracic nipples lie respectively just in advance and just behind the insertion of the forelimb and upon lines which diverge posteriorly, the thoracic being always more laterally sited. The abdomino-inguinals show considerable variation in pattern due to changes in both the lateral and antero-posterior intervals separating them. An evenly-spaced crescentic arrangement (Text Fig. 1 A) is frequent, but a rectilinear form in which the 2nd and 3rd
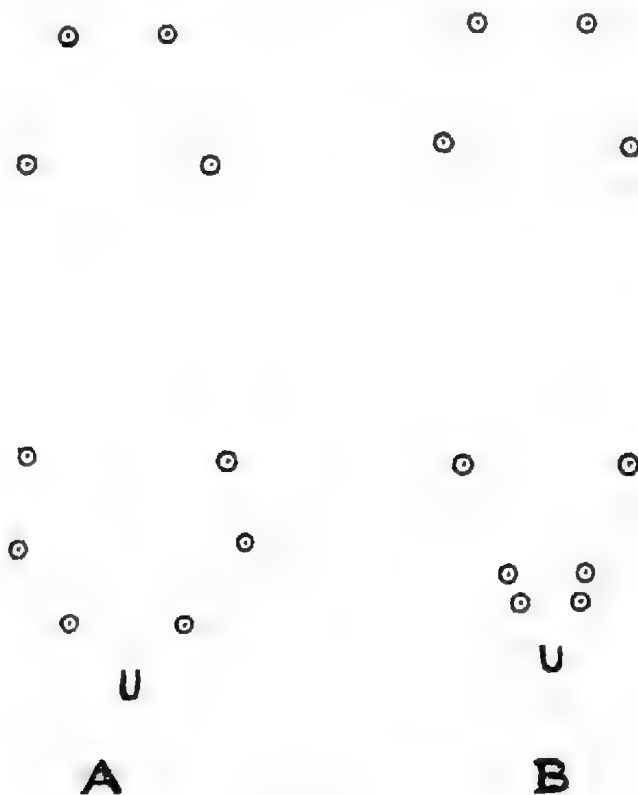


Fig. 1.
Diagram showing extremes of variation in the mammary
pattern of *R. greyi greyi* (x 1·0 ca.).

are nearer both to the midline and to one another, than to the 1st, also occurs (Text Fig. 1 B) as well as intermediate conditions. The B pattern is apparently that noted by Tate (1951) in the form *R. g. peccatus* from West Victoria. The intervals represented in the diagrams were measured with the limbs extended laterally to the maximum. The first (lower abdominal) lies well in advance of the insertion of the hind limb.

The *testis* is relatively very large and at its maximum development in the scrotum has diameters of 23 and 14 mm. approximately and weighs about 2 g.; it is as large as in the much bulkier *R. lutreola* of the same habitats, but a more squat oval in shape. The scrotum is well furred except at the caudal extremities, which are nude and have the epidermis pigmented dark gray. The epidermis of the perineal site in the female is also darkened slightly, but the pigment is

diffused and not concentrated on the two distal sites as in the male. In adults the genital tubercle has a free projection of about 8 mm. in both sexes.

Sexual variation in external characters except where noted in the account is slight or largely obscured by individual variation.

## (b) DIMENSIONS

The four chief dimensions quoted were obtained as follows: *Head and body*—This is the total length of the dorsal contour, minus the tail length. *Tail*—The length of the ventral surface of the tail from the posterior margin of the anus to apex of the last vertebra, excluding the terminal hair. The measurement is made with the tail flexed at right angles to the body. *Pes*—The length of the plantar surface from the extremity of the heel to the extremity of the most distant apical pad, excluding the claw, the digits being straightened and in line with the metatarsal. *Ear*—Length from the lowest point of the traguid notch to the apex of pinna.

The figures give the range and approximate mean for two overlapping age groups; (1) an adult plus aged group of 10 males and 6 females in which all molar crowns have sustained sufficient wear to obliterate the pattern of individual cusps and replace it by one of transverse lophs and in which rostral development is marked and the zygomatic outline untapered, and (2) an advanced subadult group of 9 males and 13 females in which all cusps show appreciable wear and the rostral development is less. In the adult group the range and approximate mean of the percentage relation of length of tail, pes, and ear, to that of head and body, follow the absolute dimensions. Head and body and tail are to the nearest mm.; others to the nearest 0·5 mm.

1. Head and body, ♂ 138-159 (146·7), ♀ 139-155 (145·0); tail, ♂ 130-153 (139·7), 84·7-110·0 (96·1) per cent., ♀ 127-146 (134·6), 83·9-104·0 (92·5) per cent.; pes, ♂ 27-32 (29·3), 17·2-22·2 (19··9) per cent., ♀ 28-28·5 (28·2), 18·1-20·1 (19·4) per cent.; ear length, ♂ 20-22 (21·1), 13·3-15·8 (14·3) per cent., ♀ 19-21·5 (20·2), 13·1-14·6 (13·9) per cent.; ear breadth, ♂ 11-13·5 (12·2), ♀ 11-13 (12·1); rhinarium to eye, ♂ 17-19 (18·4), ♀ 16-19 (17·9), eye to ear, ♂ 13·5-16 (14·5), ♀ 14-16 (15·1); weight in grammes, ♂ 80-112 (92·7), ♀ 70-90 (82·6).

2. Head and body, ♂ 120-146 (131·8), ♀ 122-145 (131·8); tail, ♂ 115-137 (125·0), ♀ 115-135 (123·2); pes, ♂ 27-30·5 (28·5), ♀ 26·5-29 (27·8); ear length, ♂ 19-21 (19·7), ♀ 18-21 (19·7); ear breadth, ♂ 10-14 (11·9), ♀ 10-13·5 (11·8); rhinarium to eye, ♂ 16-18 (17·0), ♀ 16-18 (16·9); eye to ear, ♂ 13·5-15 (14·1), ♀ 13-15 (13·8); weight in grammes, ♂ 56-85 (67·4), ♀ 51-75 (65·7).

Though there is a wide overlap in all dimensions between the sexes, it would appear that in fully adult animals, the female is approximately equal to the male in head and body length, but is decidedly lighter when non-pregnant (10 per cent.) and averages slightly shorter in pes, ear and tail. The enormous example quoted by Wood Jones (1925, 304) with a head and body length of 186 mm. has no near counterpart in this series. The very low foot length of 26 mm. associated with it, suggests that the former may be a typographical error.

## (c) PELAGE

The pelage is fine and soft and in prime condition is dense and copious and middorsally consists of three piles: (1) a fine silky underfur of nearly uniform diameter and 18 mm. long; the basal two-thirds is a deep slate (near Ridgway's

dark plumbeous) and the terminal one-third is broken up into three colour bands, successively dark brown black, a bright tan between ochraceous tawny and ochraceous orange, and the extreme tip again brown black; this pile is both quantitatively and chromatically the most important element in the pelage; (2) a second pile may reach 25 mm. in length and is made up of much smaller numbers of hairs with flat shafts which broaden in the upper third of their length; they are plumbeous at base, but with the terminal 6 mm. brown black and the extreme tip buff or ivory; (3) a sparse admixture of guards which reach 35 mm. in length and darken from plumbeous to brown black over their distal half. Posteriorly the three sets of hairs may lengthen to 20, 30 and 45 mm., respectively, and over the rump and sides an increasing proportion of the latter are tipped with white or ivory.

The general colour effect dorsally is a fine almost uniform grizzle of rich tan, brown black and buff or ivory which almost entirely obscures the basal slate colour and when viewed from a little distance approximates to Ridgway's cinnamon brown in the warmest and lightest coloured individuals, and to bistre in the coldest and darkest.

The sides are lighter than the back owing to a progressive weakening of the subterminal band to a buffy brown and reduction in the overlay of black tipped guards, but in most individuals the lateral surfaces remain distinctly grizzled and the passage to the pale ventrum is abrupt. Mid-ventrally, there are two piles: an underfur 10 mm. long with its basal 8 mm. a somewhat lighter plumbeous than dorsally and with the tips greyish white or pale buff and a sparse intermixture of guards 15 mm. long which are slate with the distal flattened 5 mm. white or near white. The basal slate shows through more than on the dorsum and the general colour here is a greyish white with a more or less decided wash of yellow or buff over the belly. Gray (1841) singled out this variation of the yellow tone of the ventrum in his original description; but in the whole of the present series it is appreciable and sometimes decided over the mid-belly, while the throat, chest and perineal areas may remain grey white. In a few examples there is an invasion of the belly area just in advance of the insertion of the hind limb, by the buff or brown of the sides.

The facial areas and crown are paler and more buffy than the back, though still well grizzled. The ear backs in dried material are usually darker than the head, chiefly owing to the blackish pigmentation of the epidermis, the very scant hairing being a pale brown externally and greyish white internally – in a small proportion, however, greyish ear backs lighter than the head are present. The outer aspects of the forelimb are greyer than elsewhere – about Ridgway's light drab, and long haired, and just above the carpus a conspicuous dark brown black marking is constantly developed, sharply contrasted with the silvery white carpus and manus; the hairs of the latter, however, are usually pale brown at base and there is sometimes a very slight grizzling of all-dark hairs over the metacarpus. The outer aspects of the hind limb are brown like the sides, with a slight darkening above the calcaneum sometimes developed, and with the dorsum of the pes as in the manus.

The tail is thinly clad with short hairs closely adpressed mid-dorsally and then lifting and lengthening slightly distally. In unfaded pelage, the dorsal surface is decidedly darker (both as to hairs and epidermis) than the ventral – the mid-dorsal hairs being near bistre darkening to near black at the apex, while on the sides and beneath they are greyish white proximally and various shades of weak brown, distally. However, as mentioned above, as a result of what are no doubt periodic changes in each individual, dark strongly bicolor tails and others which are equally pale on all surfaces, may be seen at all seasons.

Variation of a strictly individual kind is well shown by the series and may be seen in examples of equally fresh and copious pelage, trapped at the same time on the same site. In such cases it is due chiefly to marked differences in the tone and length of the subterminal band of the first pile and to the length and profusion of the black overlay of the second and third — the white tips of the latter are too sparse to have appreciable effect. In examples with a short subterminal band of relatively weak colour (ochraceous buff) with a heavy overlay of second pile and guards, dark blackish brown scarcely grizzled coats result, whereas, with a broad richly coloured band of ochraceous orange and few guards, the coat becomes strongly rufescent and appears markedly grizzled.

In addition to these individual differences, there are others due to progressive fading and delapidation of the pelage, resulting in a general weakening of the colour and a change of hue, caused by the showing through of the slate basal colour zone of all three piles. This leads to pale fluffy coats of a slightly avellaneous tinge, approaching wood brown, which is also more or less characteristic of early immaturity. I am of opinion that this phase has unduly influenced some existing descriptions of the species. Wood Jones, for example, in emphatically repudiating Ogilby's (1892) description, states that there is no "intense reddish" anywhere in the coat and that the smoky colour of the underfur shows through and subdues the whole. This, however, is not true of the pelage at its best as described above, and it would be difficult to avoid the terms "red brown" and "blackish brown" in ordinary parlance, in defining such.

Although the area has a hot summer and comparatively sharp winter with marked difference of mean day temperatures in February and July, seasonal differences in the pelage are at a minimum. While the richest pelage of the series was taken in August others of almost equal quality were seen in February and May, and conversely, worn, short and faded coats were obtained in all three months. The time of renewal of the coat is evidently an individual matter independent of seasonal conditions and following a cycle determined largely by the time at which the rat was littered. No evidence of an orderly moult proceeding successively over different areas of the surface, with well marked boundaries between the old and new coats, could be detected; but in two individuals taken in May, large areas of both dorsal and ventral surfaces, simultaneously, showed a short replacing coat mingling with the base of the main pile. No valid sexual differences in pelage could be traced.

### (d) CRANIAL AND DENTAL CHARACTERS

Twenty skulls, all extracted from animals of known external characters and dimensions, have been examined and measured.

The skull (Pl. 1, Figs. A-D) is notable for its smoothly rounded outlines and weak muscular impressions, which are retained without appreciable alteration into advanced age. This gives it a distinctive appearance which at once marks it off from other Australian species of *Rattus*, and recalls somewhat the form of the larger species of *Pseudomys s.s.*

The muzzle is of moderate length but very narrow and with a marked tendency to parallelism of its sides. The maximum width of nasals is always subterminal, but fluctuates over a 20 per cent. range, with corresponding variation in the overall shape of the bones which, however, never develop an abrupt or bulbous expansion. The fronto-nasal suture is usually broad and square and the premaxilliary process may overlap it posteriorly or fall short. The zygomatic outline is broad with some flattening at the mid point of the curve and with

the maximum width always at the squamosal root, but in adults the middle
width is almost as great and it is only in distinctly subadult skulls that there
is any appreciable posterior taper of the arch. The interorbital region tends
to be tubular and smooth, and the supraorbital margins are not ridged. The
brain case is broad and smoothly rounded and temporal crests are only slightly
developed or even quite absent. The lacrymals are large, and the anteorbital
fossae, though variable, are never strongly developed and are sometimes con-
spicuously small.

In lateral aspect the dorsal profile is well arched but less so than in such
forms as *R. culmorum* and *R. lutreola*. The zygomatic plate is shorter vertic-
ally than in *R. assimilis*, but is otherwise similar and its anterior margin may be
either strictly vertical or with a slight concavity at base. Conflicting statements
have been made about the size and shape of the anterior palatal foramina in
*R. greyi* and their relation to that of *R. assimilis*. In the present series the adult
condition is that length is comparatively constant and always decidedly greater
than the molar rows, but width (like that of the nasals) is one of the most
variable of dimensions, with a range of 15 per cent. or more — however, in
relation to such species as *R. culmorum* and *lutreola* they could only be described
as wide, and though the exact shape is variable, their combined aperture does
not narrow posteriorly at all markedly as in *assimilis* and is sometimes as wide
posteriorly as in the middle. The bullae are small with their length about equal
to that of the molar rows, but they are relatively broad and well rounded.

Age changes in the skull are less marked than usual, but can generally be
recognised in the change in shape of the zygomatic arches above mentioned and
in the elongation of braincase and rostrum. Sexual differences are inappreciable
in the subadult group; in that of adults the largest example is from a very aged
male and is disproportionately enlarged in relation to its somatic dimensions —
whether females equally enlarged occur, the material is insufficient to determine.

In the molars (Pl. 1, Figs. E and F), small but distinctly developed an-
terior cingular cusplets can be made out on $M^1$ in about one-third of the im-
mature skulls and vestiges of them persist in one or two adult dentitions. The
buccal element (T.3) of the first lamina of the same tooth is usually very com-
p'etely suppressed but is weakly indicated in a few examples. In the lower
molars the interproximal accessory cusps of $M_1$ and $M_2$ are always present in
unworn teeth, but are often very small and are frequently eliminated from
the adult dentition by wear. The rate of molar wear is subject to much irre-
gularity owing, no doubt, to varying amounts of earthy abrasive ingested with
the food, and the crown pattern by itself is only a very rough guide to age.
There are several examples in the series of distinctly immature animals judged
by somatic and cranial characters, in which the cusps of all the laminae are
transversely linked by broad bands of dentine.

The following figures give in turn the range and approximate mean of the
skull measurements and molar rows for (1) five males and two females in the
adult group as defined (*supra*), and (2) five males and four females in the
subadult group:

Greatest length, ♂ 35·7-38·7 (36·7), ♀ 35·8-36·9 (36·3), ♂ 33·0-35·0
(33·7), ♀ 32·6-34·3 (33·6); basal length, ♂ 31·0-34·3 (32·3), ♀ 31·6-32·5
(32·0), ♂ 28·6-30·1 (29·1), ♀ 28·5-30·4 (29·5); zygomatic breadth, ♂ 17·5-
18·9 (17·9, ♀ 18·1-18·2 (18·15), ♂ 16·9-17·5 (17·0), ♀ 16·3-17·2 (16·9);
interorbital breadth, ♂ 5·0-5·7 (5·4), ♀ 4·8-5·1 (4·9), ♂ 5·0-5·5 (5·2), ♀
5·0-5·0 (5·0); nasals length, ♂ 13·2-14·5 (13·8), ♀ 13·8-14·0 (13·9), ♂
12·2-13·0 (12·6), ♀ 11·6-12·7 (12·1); nasals greatest breadth, ♂ 3·3-4·1
(3·5), ♀ 3·8-3·8 (3·8), ♂ 3·2-3·9 (3·6), ♀ 3·3-3·5 (3·4); palatal length,

♂ 18·6-20·5 (19·3), ♀ 19·2-19·2 (19·2), ♂ 17·5-18·1 (17·8), ♀ 17·3-18·2 (17·7)· anterior palatal foramina, length, ♂ 7·2-7·5 (7·3), ♀ 7·3-7·3 (7·3), ♂ 6·5-6·8 (6·7), ♀ 6·5-7·0 (6·6); *ditto*, breadth, ♂ 2·3-2·7 (2·5), ♀ 2·3-2·4 (2·35), ♂ 2·0-2·4 (2·2), ♀ 2·0-2·3 (2·2); bulla, length, ♂ 6·1-6·7 (6·3), ♀ 6·0-6·1 (6·05), ♂ 5·8-6·3 (6·0), ♀ 5·8-6·3 (6·1); Ms.$^{1-3}$, ♂ 6·2-6·3 (6·26), ♀ 5·8-5·9 (5·85), ♂ 5·8-6·3 (6·1), ♀ 5·9-6·3 (6·1).

## 3. OTHER POPULATIONS OF *R. GREYI*

### (a) MAINLAND DISTRICTS NORTH OF FLEURIEU PENINSULA

A group of ten specimens from hill tracts north of the Fleurieu Peninsula in the valleys of the Sturt and Onkaparinga, offer no appreciable distinction from the standard series. Two examples are slightly shorter tailed and another gives an extralimital value of 58 mm. for mysticial vibrissae.

Three female specimens from a mangrove swamp near the mouth of the Gawler River about 20 miles north of Adelaide on the Adelaide-Wakefield plain in a very different environment from the Hills series, are of interest as showing the first signs of significant differentiation. While in full agreement with the standard series in external characters and pelage, they carry the shortening of the tail a stage further (min. 78 per cent.) and are longer footed (29-29·5 mm.). One of them provides the largest female skull from the South Australian mainland, measured (greatest length 27·3) and the anterior palatal foramina are longer and narrower (7·5-7·6 and 2·1-2·1), and the molar rows just below the lower limit of the range (5·7-5·8) and the individual teeth narrower than in the standards.

I have no relevant material on which to base an independent opinion as to the extent of the westward extension of *R. greyi greyi* on the mainland, but both Iredale and Troughton (1934, 72) and Tate (1951, 329) record it from Pt. Lincoln on Eyre Peninsula. Tate's position in so doing was only made tenable by his willingness to accept Kangaroo Island as the type locality of the form which he regarded as *R. greyi austrinus*. But the few specimens from Kangaroo Island which I have examined convince me that the form of *R. greyi* which occurs there does not represent *austrinus* as defined by Thomas, and is, in fact, very doubtfully separable from the typical Fleurieu race on the opposite shore of Backstairs Passage.

In spite of Thomas's assumption that his *R. culmorum austrinus* was "a common form in South Australia in the 1840's", it does not seem to have found its way into any local collections, and its origins are as obscure as when described. But whether it came from Kangaroo Island or Eyre Peninsula, or formerly occurred on both, its place, on a basis of described characters, seems to be definitely with *culmorum* and not *greyi*, and it is not further considered here.

Tentatively and as a working hypothesis I accept the above opinion on the range of *R. greyi greyi*, but the Gawler River specimens suggest that the case may have been less simple than that.

### (b) GREENLY ISLAND

This site is a steep granite ridge with a peak of 750 feet at the eastern end and two semidetached masses at the western end, lying about 19 miles west-south-west of Point Whidbey on the west coast of Eyre Peninsula. The

greater part of the island surface consists of unbroken rock slides, but near the summit and on the south slope where some remnants of the original limestone capping persist there is a stunted forest of *Casuarina stricta* trees and thickets of the same species in bush form, together with *Melaleucas*, and *Correas* occur on broken areas of the north slope. There is a considerable small flora in suitable localities where soil has accumulated, including such genera as *Atriplex, Rhagodia, Frankenia* and *Calandrinula*.

The island is uninhabited and seldom visited. The writer made a six days stay there in November, 1947, to investigate the local wallaby, tracks of which had been seen by Wood Jones (1923), and found a form of *Rattus greyi* abundant on the main mass of the island. It apparently does not burrow and there are few parts of the island where it could indulge such a habit except on a very limited scale, but there is ample ground cover in debris under the she-oak timber and in the denser thickets and it evidently camps in such shelter and in rock crannies. It is much less sophisticated and shy than its mainland relatives, and was frequently seen foraging about in the more open parts in the late afternoons and at night it invaded the camp in numbers and could be freely inspected in a torch beam at a distance of a foot or so – in the beam the eye is blood red. It was extremely noisy, ransacking all camp gear and sampling all provisions left unprotected. Although it must of necessity be largely vegetarian, it showed a strong partiality for flesh foods at the camp and mutilated wallaby carcasses left there. The stomach contents of those examined consisted largely of tuberous vegetable material with seed case fragments and in two cases insects and remains of a (?) gecko.

The material on which the following account is based comprises 23 individuals, belonging to three collections all from the main island, two made personally in November, 1947, and February, 1949, respectively, and a third by a party which included South Australian Museum personnel, in December, 1947. The sex ratio in the combined collection is 16 ♂ : 7 ♀. During November and December reproduction was evidently active, all males having enlarged scrotal testes and some females lactating, though no young were taken; in February, however, when only females were taken, their condition was quiescent, with occluded vulvae and strongly retracted nipples.

Ectoparasites were present in large numbers and have been found by H. Womersley to include two species of fleas, *Xenyllopsis cheopis* and *Cerataphyllus fasciatus;* two species of acarids, *Laelaps nuttali* Hirst and *Haemaphysalis leachi* Aud., and the louse *Hoplopleura bidentata*. Of endoparasites an extraordinarily heavy stomach infestation of nematodes was found in several individuals and these have been tentatively identified by Mrs. I. M. Thomas as species of *Physaloptera* and *Protospirura*. About one-third of the specimens examined showed pathological conditions in the tail and manus and pes, with malformation of digits and ulceration of the papillae of facial vibrissae. In spite of these afflictions, however, the rats were commonly vigorous and well nourished, and sometimes fat.

The Greenly Island rat has attained a considerable level of differentiation both from that of the standard series of the Fleurieu Peninsula and from its nearer neighbour *R. greyi murrayi* Thos. of the Pearson Islands, about 60 miles to the nor'west.

It is nearer the latter, especially in the more obvious characters of pelage, but in other important respects is quite distinct and I propose to separate it subspecifically as

## RATTUS GREYI PELORI subsp. nov.

It may be diagnosed with respect to *R. g. murrayi*, as follows:

A relatively large form, and when fully adult, thickset and bulky and with powerful hands and feet. General size considerably exceedingly *murrayi* and the tail and pes longer both absolutely and relative to head and body; the pes much modified, broader and with structural differences noted below; tail scales finer; pelage still paler and more grizzled, the ear backs lighter than the head, not darker, and the precarpal bar conspicuous. In the skull the anterior palatal foramina are shorter and the dentition less reduced.

The longest mysticial vibrissa in 13 apparently undamaged examples gave a range and approximate mean of 38-58 (45). The ear is thick in substance and relatively broad with a B/L ratio of ·63-·75 (·69). The manus is stouter than in the Fleurieu series, the B/L ratio averaging ·42 as against ·37, and though the size sequence of the pads is the same, the individual pads are stouter and more squat and the metacarpals nearly always subequal. The pes is also notably large and broad, the breadth ranging from 7-8·5 and the B/L value from ·22-·27 (·25) as against ·21-·24 (·22). The pad sequence is much the same, but the inner metatarsal tends to be smaller and narrower, while the rest of the pads, especially the interdigitals 1 and 4 are rounder. Fresh or alcoholic specimens of *R. g. murrayi* suitable for accurate measurement have not been available, but direct comparison of dried material of all three forms has shown that the agreement of *murrayi* in manus and pes is with the standard Fleurieu series rather than with that of Greenly Island and the above metrical comparison of the two latter is inserted to give an approximate estimate of the difference. The tail is stout and, by mainland standards, short although less so than in *murrayi*, the mean percentage of head and body length being 88 per cent. as against 77 per cent. in the latter; the scale rows are constantly 15 per cm. middorsally in adults, rising to 17 in subadults, as against 12-13 in adults of *murrayi*.

The pelage is subject to much heavier wear than has been observed on the mainland and, as a consequence, differences due to this factor are correspondingly high. The November and December batches contain many thin and lax coats, largely denuded of guards on the rump and with a short replacement coat showing basally here and there on the dorsum. In February, however, the pelage was prime and in point of density about equal to that of the Fleurieu series dorsally, but always thinner ventrally. In spite of these differences, the general colour range is less than in the latter. The following notes are based chiefly on the prime pelage. Middorsally the three piles average 16, 18 and 20 mm. in length, respectively, with guards on the posterior back from 40-45 mm. The subterminal band is a weak yellowish buff, never brown nor rufous, and is longer with less black or brown annulation and less overlay from the guards. The general dorsal colour is a somewhat olivaceous[1] grey brown, near Ridgway's drab, very uniform from the crown of the head to tail base in good pelage but irregularly mottled with wear, and with a tendency in November skins to a warmer scapular and darker lumbar area. The ear backs are paler than the head in dried skins though not always appearing so in life. The sides are cold drab merging imperceptibly with the ventrum which is pale plumbeous basally for three-quarters of its length and weakly tipped with ivory buff, the general effect near drab grey. Manus and pes may be pure white or feebly grizzled with drab or brown and there is always a conspicuous dark precarpal bar on the outer aspect of the forelimb. The tail is long-haired as in *murrayi* with hairs 3-3·5 scales in length when not abraded, and rather erect; its colour

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[1] A skin in the South Australian Museum made up from alcohol after 12 years immersion, shows marked changes from the fresh condition here described.

variable but most frequently a pale drab on all surfaces and with no dorso-ventral contrast.

In pelage *R. g. pelori* shows the same divergent trends from *R. g. greyi* as *R. g. murrayi* does, but carries them a stage further resulting in increased pallor, weaker and yellower subterminal colour and more conspicuous dorsal grizzling, especially on the head where the ear backs are lighter, not darker. In the five skins of *murrayi* which have been used in the comparison the tail is much darker on all surfaces than in the new form but the standard series has shown this character to be so unstable that I hesitate to advance it as a good distinction.

*Flesh Dimensions*—The following figures give in turn the range and approximate mean for five adult ♂ and five adult ♀, and of the type ♂. Head and body, 158-168 (162·8), 147-162 (154·0), 168; tail, 127-145 (135·7), 137-142 (139·7), 142; pes, 31-32 (31·3), 30·5-31·5 (31·0), 31·5; ear length, 20-20·5 (20·2), 19·5-20 (19·9), 20·5; ear breadth, 13-15 (14·0), 13-14 (13·5), 13; weight in grammes, 110-111 (110·5), 94-105 (98·8), 110.

The adult skull is slightly larger than that of *R. g. murrayi*, but otherwise is in general agreement with it and in particular shares (in varying degree) the three main distinctions of the latter from *R. g. greyi* as defined (*supra*), i.e., slightly greater rostral length, slightly broader bulla, and decidedly reduced molar rows. It differs from *murrayi* in a wider interorbital region, shorter anterior palatal foramina and in a smaller degree of molar reduction, especially noticeable in transverse diameters, which are scarcely below the Fleurieu standards. Other minor differences from *R. greyi greyi* of an average kind are shown in the interparietal which in adults are smaller; in the zygomatic plate which tends to be higher and with a slightly different curvature of the free margin and in the posterior margin of the palate which is evenly rounded and not produced into a spur or prominence at the palation.

*Skull dimensions*—The following figures give, in turn, the range and approximate mean for five adult ♂, three adult ♀, and the type ♂: Greatest length, 36·6-39·0 (37·6), 36·0-37·3 (36·6), 37·5; basal length, 32·1-35·6 (33·7), 32·0-33·0 (32·4), 34·0; zygomatic breadth, 18·5-19·6 (18·9), 18·4-18·5 (18·47), 19·0; interorbital breadth, 5·5-5·6 (5·56), 5·5-5·6 (5·57), 5·5; nasals length, 14·2-14·8 (14·5), 13·7-14·5 (14·1), 14·8; nasals greatest breadth, 3·7-4·0 (3·8), 3·6-3·7 (3·67), 3·7; palatal length, 18·6-20·7 (19·6), 19·0-19·8 (19·3), 20·1; anterior palatal foramina, length, 6·8-7·2 (7·0), 6·7-6·7 (6·7), 7·1; anterior palatal foramina, breadth, 2·3-2·6 (2·4), 2·2-2·5 (2·3), 2·5; bulla length, 6·2-6·6 (6·4), 6·1-6·2 (6·17), 6·4; Ms.$^1$ $^3$, 5·6-5·9 (5·8), 5·5-5·8 (5·7), 5·9.

*Type*—Adult male; South Australian Museum, registered number M.6268; a field-made skin and prepared skull collected by the writer in November, 1947, on the north slope of the main mass of Greenly Island, at approximately 34°39′S. lat. and 134°49′E. longt.

### (c) NORTH GAMBIER ISLAND

This islet of a few hundred acres, and about 150 feet high, lies about a mile and one-half north of the much larger Wedge Island in the Gambier Group at the mouth of Spencer Gulf at 35°08′S. lat. and 136°28′E. longt. approximately.

It is believed to be waterless and has never had human occupation, but long ago—possibly as early as 1820—goats were introduced and have persisted to the present time, and provide an attraction for fishing cutters in search of fresh meat. Originally, the central portions of the plateau were well grassed with *Danthonia* and supported groves of well-grown *Casuarina* trees, but as

a result of an erosion cycle which I have sketched elsewhere (1931), this area has now been denuded to the limestone and only a narrow belt of bush vegetation remains surrounding it on the cliff tops. This vegetated zone is colonized by mutton birds (*Puffinus* sp.) which burrow and by a local form of *Rattus greyi*, which lives chiefly under the tangle of a sprawling bush, *Nitraria schoberi*. The rat was formerly in very large numbers, and boat crews killed them in sport by lifting up the tangle and sending terriers in after them. Although now much reduced, it still seems to have a good hold on these parts of the island, but in a short daylight visit in February, 1949, I succeeded in trapping only three among the limestone blocks of the cliffs on the south-east coast.

These were two males and one female; one of the males with enlarged scrotal testes, the other retracted and the female apparently reproductively quiescent. A motile ectoparasite (? *Hoplopleura*) was noted, but not collected.

Externally, this rat is somewhat intermediate between that of Greenly and Pearson Isles. It is slightly smaller than the former and has a slightly longer and narrower ear, though still broad by mainland standards. The pes, although smaller, is of the same broad robust type, with similarly rounded though smaller pads. Mystical vibrissae range from 47-55 (50); the tail scales are coarser, 13-14 per cm., and the tail hairs shorter, 2-2.5 scales length. The tone of the dorsal pelage is slightly warmer, but the general condition very similar; manus and pes pure white as they are in a proportion of the Greenly rat.

*Flesh Dimensions* of the two ♂, and one ♀ are as follows: Head and body, 153-155, 132; tail, 123-136, 130; pes, 29-29, 27; ear length, 21-21, 21; ear breadth, 13-13, 14; weight in grammes, 100-105, 80.

The skull if regarded as fully adult, as the molar wear and zygomatic shape suggest, is the smallest examined in this work and as compared with that of Greenly Island is weak, and fragile and lightly ossified. The nasals and rostrum are shorter and weaker, the bullae smaller, and the anterior palatal foramina slightly longer, but the molars are within the range and therefore comparatively large, in so small a skull.

*Skull dimensions* of the two ♂ and one ♀ are respectively: Greatest length, 35.0-35.2, 35.2; basal length, 30.0-31.0, 31.4; zygomatic breadth, 17.3-17.7, 18.0; interorbital breadth, 5.1-5.3, 5.2; nasals length, 12.9-13.2, 13.0; nasals breadth, 3.5-3.8, 3.5; palatal length, 17.9-18.6, 18.5; anterior palatal foramina, length, 7.2-7.2, 7.4; bulla, length, —, 6.0, 5.9; $Ms.^{1-3}$, 5.7-5.8, 5.7.

If the characters of the Gambier Island population are reliably represented by these three specimens, it would appear to differ appreciably from that of both Greenly and Pearson islands and, while nearer these, shows some links with the mainland phase from the Gawler River, but with a marked reduction in skull size. The clearances in characters, however, are so small that I have not felt justified in basing another name upon so little material, and defer a decision on its status until an adequate series can be assembled.

Evidence of varying value from miscellaneous sources indicates that "native" rats, presumably of the *R. greyi* type, exist or formerly occurred on several other islands off the South Australian coast, besides those already listed, including the main island of the North Neptune group, Hopkin's, Taylor's, Eyre's, Goat, St. Francis and St. Peter's.

### (d) SOUTH-WESTERN VICTORIA

Brazenor (1936) reported on a large series of *R. greyi* from the Portland district, which he compared with both "South Australian" *R. greyi* and with Victorian *assimilis*, and separated subspecifically from the former. Although I agree with his chief findings the first of his comparisons was hampered by

shortage of material and some emendation and amplification of both are called for. The following notes are based upon a batch of twelve taken at Heathmere in December, 1937, and on the east bank of the Glenelg River about 20 miles north-west of that place, in June, 1951. These localities are only 10-20 miles north of Portland in a similar environment and the material is regarded as topotypical of *R. g. peccatus*.

In habits this form differs from *R. greyi greyi* of the Fleurieu Peninsula in being a more consistent burrower; this was confirmed both at Heathmere and on the Glenelg where it was quite numerous, but I doubt whether burrows were plentiful enough to shelter the whole population, part of which probably makes use of surface camps. In December at Heathmere all adult males taken showed enlarged and scrotal testes and females were pregnant.

The range in dimensions shows a plus overlap in the chief items with means averaging about 8 per cent. higher than in the standard series of *R. greyi greyi*. In relation to head and body, the tail and, to a lesser extent, the pes, are longer in the female than in that form, but this change is not shared by the male. Ignoring the sexual difference, it would appear that the chief distinction in the dimensions of the Victorian animal is in an increase of overall size and in a somewhat narrower ear. Brazenor's means of 20 selected specimens are decidedly below mine in ear and pes (and skull length also, see *infra*) and his sample probably includes what is here regarded as a definitely subadult element. I am unable to substantiate his finding that the female is necessarily smaller in linear dimensions than the male, when fully adult as judged by skull characters, nor is this the case with the standard series of *R. g. greyi*, and its use as a differential character against *assimilis* is, I think, invalid. The other metrical proposition which he uses differentially, i.e., that in large specimens of *greyi* the tail is relatively shorter than in small, I am unable to test adequately with *peccatus* or *assimilis*, but it seems to work out in the standard series where (ignoring sex) the six largest give a per cent. tail length of 84-110 (91·6) as against 93-110 (100·7) for the six smallest:

The manus and pes are very similar to those of *R. g. greyi*, the former perhaps a little heavier, but the pes, unlike that of *assimilis*, even narrower. The pads are of the same type, with distinctly angular lateral interdigitals. The mysticial vibrissae range from 47-50 (49) and the tail scales are slightly coarser, with 11-13 (12·6) per cm. middorsally. The mammary pattern, discussed by Tate (1951, 330) in connection with this subspecies, is not characteristic of it, but occurs (with variants) in *R. g. greyi* as well. (*Supra.*)

In the pelage characters of the body, the West Victorian series can be completely merged in that of the Fleurieu Peninsula; it does not yield any examples of the rich coppery variants of the latter, but all its other phases can be closely matched therein, and it offers nothing novel in tone, grizzling or pattern; it is certainly not darker as a whole. On the dorsum of manus and pes the hairs are always decidedly darkened at base and this leads to occasional grizzling, particularly when the covering is sparse, and there are two cases of all dark hairs at base of the claws not noted in other groups. The precarpal bar is usually fainter and sometimes lost, but on the inner aspect of the lower surface of the carpus there is frequently a tract of adpressed, contrasted brown hairs outlining the bases of the metacarpal pads, absent, or very feebly indicated, in the Fleurieu series. The tail is usually appreciably darker above than below, as in the latter, but there are equally striking variations both in its colour and in the prominence of the scale rings. In worn pelage where replacement has begun, there is a tendency for a darker lumbar patch to be isolated as in the November skins from Greenly Island.

*Flesh Dimensions*—The following figures give in turn the range and approximate mean for the dimensions of three ♂ and four ♀, adult. Head and body, 152-169 (160·0), 153-166 (156·0); tail, 138-155 (149·0), 140-163 (154·7); pes, 31·5-33·5 (32·5), 30-32·5 (31·6); ear, length, 22-23 (22·5), 21-23 (22·5); ear, breadth, 13·6-13·8 (13·7), 13·8-15·0 (14·4); weight in grammes 100-130 (115·0), 85-130 (110·0).

The adult skull is larger than in *R. greyi greyi*, with the female giving higher values in most measurements than males. The range in the majority of items shows a plus overlap with that of the standards with an average increase in the means of the order of 5 per cent. in most longitudinal dimensions. It is relatively narrower zygomatically, with slightly longer rostrum and relatively shorter tooth rows with broader molars. A notable nonmetrical distinction from the primary form is to be found in the temporal crests, which are more strongly developed and produced anteriorly on to the supraorbital margins which in consequence are distinctly ridged.

*Skull Dimensions*—The range and approximate mean follow in turn for four adult ♂, three adult ♀, and a single anomalous stunted adult or aged ♀, which gives values below the minima for the Fleurieu series, and which cannot be regarded as a normal intergrade between *R. g. greyi* and *peccatus*:—Greatest length, 36·9-38·5 (37·5), 37·7-38·8 (38·2), 34·0; basal length, 32·8-35·0 (33·8), 33·6-34·3 (33·9), 29·8; zygomatic breadth, 18·3-18·9 (18·5), 18·3-18·7 (18·5), 17·3; interorbital breadth, 5·3-5·5 (5·4), 5·3-5·5 (5·4), 5·1; nasals length, 14·2-15·6 (14·8), 15·0-15·2 (15·1), 13·0; nasals greatest breadth, 3·7-4·0 (3·9), 3·6-3·8 (3·7), 3·6; palatal length, 19·6-21·5 (20·2), 20·3-20·6 (20·4), 18·1; anterior palatal foramina, length, 7·3-8·0 (7·6), 7·9-8·0 (7·95), 6·8; anterior palatal foramina, breadth, 2·5-2·8 (2·6), 2·5-2·5 (2·5), 2·5; bulla, length, 6·5-6·6 (6·55), 6·5-6·8 (6·6), 5·9; Ms.[1-3], 5·9-6·4 (6·1), 6·0-6·4 (6·2), 5·5.

*Rattus greyi peccatus* is undoubtedly a valid form, recognisable beyond the limits of the conventional 75 per cent. allocation, by metrical, pelage and cranial characters. It is at present known from a very restricted area of south-western Victoria at sea level, in ecological conditions appreciably different from those of the South Australian highlands, which harbour the primary subspecies. To what extent it interdiffuses with *assimilis* to the east and how effective the Glenelg River is as a barrier to its westerly drift, are matters which await further field work.

## 3. *RATTUS ASSIMILIS* GOULD

The relationships of this species to *R. greyi peccatus*, to which it bears much external resemblance, have been examined by Brazenor (1936) in broad outline with a large series of Victorian specimens. There is need, however, for a more detailed statement of its characters and range of variation before these can be regarded as well established. The material in hand is inadequate for this, but for the purpose of a limited and provisional check, skins and skulls of some 15 individuals are available. These belong to two batches personally taken in January, 1928, on upper Ryan's Creek in the Tolmie district of northeast Victoria, and in December, 1928, at Hillas Brook in the Batlow district of southern New South Wales. Both localities are highland sites, the second above 3,000 feet. In addition, I have examined miscellaneous specimens from French Island in Westernport Bay, Victoria, and from Dorrigo and the Barrington Tops in New South Wales. At the Ryan's Creek camp the species was plen-

tiful though not at all obtrusive and was first taken unintentionally in wallaby and opossum snares under tree ferns in a wet gully and later was trapped with bread baits in the undergrowth of dense wattle scrubs. At Hillas Brook it was taken in the same way under bracken in more open valleys of big eucalypts, and a few also in a barn where they had begun to raid potatoes in sacks – a type of depredation which *R. greyi* in South Australia never seems to attempt. Whether this combined series is as homogeneous subspecifically as current nomenclature would imply, may be questioned but it suffices for a general appraisal of the *R. g. peccatus-assimilis* relation.

Dimensions of adults just overlap the maxima for those of *peccatus*, as quoted above, in head and body, pes and ear, but the means are higher, decidedly so (10-12 per cent.) in the case of the first. The means for tail length are equal in the case of the males and lower with the single female. Proportionally to head and body, therefore, the pes and ear are slightly shorter than in *peccatus*, and the tail markedly so, with a mean for the two sexes of 83 per cent. as against 95 per cent. in the latter; this finding is supported by the short-tailed condition of the cotypes (80-84 per cent.), but conflicts with Brazenor's 101 per cent. as a mean for 20 *assimilis*. No weights are available, but would probably be much higher than for any form of *R. greyi*

In dried specimens both manus and pes appear to be much stouter than in *R. g. peccatus*, though the pads are of the same general type. Brazenor, however (*op. cit.* Pl. XIII, 2 d) figures a somewhat more elongated inner metatarsal. In the manus the digital rings are increased to 6 and, in the pes, to 8, and they are less divided than in the forms of *R. greyi*. Mysticial vibrissae in five undamaged adults range from 59-67 (61), which is much longer than in *peccatus* and the tail scales are slightly coarser, 11-12 (11·7) per cm.

In pelage characters the group shows an extraordinary range of variation, due partly to phase, but partly to local or individual influences, and it is obvious that until comprehensive series are examined illustrating the entire sequence of the coat replacement, only tentative conclusions are possible under this head. Brazenor (1936, 67) has already stated that the pelage of *assimilis* is indistinguishable from that of *R. greyi peccatus* of the Portland district. So far as the Victorian specimens of the present series are concerned, this is substantially true. The single French Island skin is much richer coloured and more cupreous in tone than any of my *peccatus*, though it can be matched in the Fleurieu Peninsula, and of the remainder it is generally true that the coat is somewhat more spinous dorsally, the darkening of manus and pes more frequent, and the presence of the brown infracarpal tract more constant than in the latter. The precarpal bar is present in two skins only. The New South Wales examples from Batlow and Dungog are appreciably distinct being colder in tone and with a finer ticking.

*Flesh Dimensions* – Four adult males and one adult female give the following values:—Head and body, 168-195 (179), 173; tail, 143-157 (150), 142; pes, 33-35 (33·5), 34; ear length, 22-24 (23·2), 23.

Skull size in these two groups is consistently much larger at all comparable stages of growth than in *R. g. peccatus*. The range in seven of the eleven dimensions studied shows a plus clearance from that of the latter, with the means of the chief longitudinal dimensions 10 per cent. higher, and the overall superiority in size is still more impressive in direct visual comparison. The chief departures from coproportionality with *peccatus* as gauged by the percentage relation to the greatest length of skull, are: Shorter rostrum, shorter and much narrower anterior palatal foramina (− 6 and − 25 per cent. respectively), shorter bulla (− 10 per cent.), and longer molar rows (+ 14 per cent.).

In nonmetrical cranial characters there is considerable variation and overlap, but the following may be noted as valid differential trends. In the nasals there is a distal shift in the maximum width which leads to a straight, more wedge-shaped outline than is usual in any of the forms of *R. greyi*; the temporal and supraorbital ridges are similar in outline but more strongly developed; the dorsal profile is straighter and less arched; and the posterior half of the anterior palatal foramina is more narrowed and parallel-sided than the anterior, with a characteristic change of shape.

One skull presents the anomaly of a paired interparietal (Pl. 1, Fig. G).

*Skull Dimensions* – The values for seven adult males are as follows:—Greatest length 40·0-43·1 (41·4); basal length, 35·3-39·1 (36·9); zygomatic breadth, 20·0-21·4 (20·8); interorbital breadth, 5·7-6·0 (5·9); nasals lengths, 15·0-17·0 (15·7); nasals greatest breadth, 4·1-4·5 (4·3); palatal length, 21·6-23·5 (22·5); anterior palatal foramina, length, 7·5-8·3 (7·9); anterior palatal foramina, breadth, 2·0-2·5 (2·3); bullae, length, 6·2-6·7 (6·5); Ms.$^{1-3}$, 7·0-7·6 (7·3).

## 5. INTERRELATION OF *R. ASSIMILIS*, *R. GREYI* AND *R. FUSCIPES* WATERHOUSE

Ellerman (1949) considered *R. assimilis* and *R. greyi* to be conspecific, a view with which Tate (1951) evidently sympathised, though he did not give effect to it in nomenclature. Though they are undoubtedly very closely related animals, a study of the two forms, which may be assumed to be in contact in mid-Western Victoria, has convinced me that the differences separating them are more than subspecific and confirms me in the opposite and older view. Although occasional specimens may transgress the limits of the three groups, a more or less clinal relation in general body size subsists between the east to west series, *R. assimilis* (?*assimilis*), *R. greyi peccatus*, and *R. greyi greyi*, with a much steeper gap between the first two forms, but this trend is not continued into the offshore colonies of Eyre Peninsula where, in the case of *R. g. pelori* at least, a slight secondary enlargement has taken place.

These island forms, although well differentiated, have so many unmistakable links with the Fleurieu Peninsula population that their relegation to *R. greyi* seems the only natural course. The alternative allocation to *R. fuscipes*, which is regarded as having a modified representative on Mondrain Island on the continental shelf of Western Australia, has some attractions on palaeogeographic grounds and is foreshadowed in the views of Ellerman (*op. cit.*). I have not tested this *de novo*, but if the generally accepted links of *R. fuscipes* with *R. lutreola* are well founded (and they have been recently reaffirmed by Tate (1951) with good material), it would seem to be strongly contraindicated. None of the forms here considered show any convergence cranially to *R. lutreola* as known in South Australia.

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PLATE 1

A



B

A

B

C

D
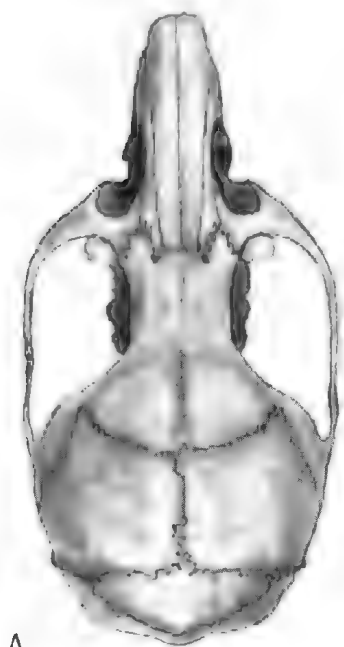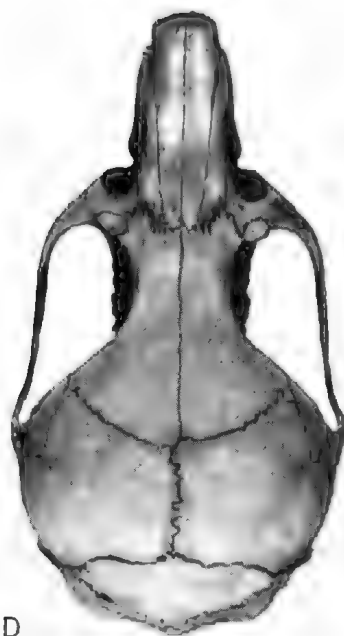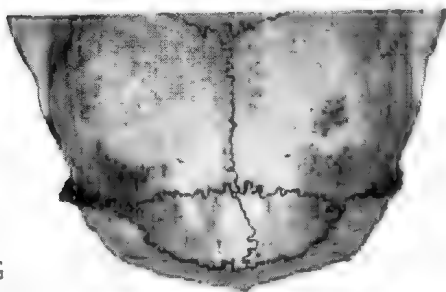
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## EXPLANATION OF PLATES

### PLATE 1

Fig. A. Dorsal aspect of the skull of an adult ♂ of *Rattus greyi greyi* Gray from the Callawonga Creek, Fleurieu Peninsula, South Australia (x 2·1).

Fig. B. Lateral aspect of the same (x 2·1).

Fig. C. Palatal aspect of the same (x 2·1).

Fig. D. Dorsal aspect of the skull of a subadult ♂ of the same from the Boat Harbour Creek,[1] Fleurieu Peninsula, South Australia (x 2·3).

Fig. E. Slightly worn right upper molars of an immature ♀ of the same from the same locality (x 7·1).

Fig. F. Well worn right upper molars of an adult ♂ of the same from the Yankalilla Creek, Fleurieu Peninsula, South Australia (x 7·4).

Fig. G. A paired interparietal bone in the skull of an adult ♂ of *Rattus assimilis*, from upper Ryan's Creek, Tolmie district of north-east Victoria (x 2·7).

### PLATE 2

Grass nests constructed by *R. greyi greyi* in captivity, with the builder in occupation.

Fig. A. A simple open type nest (x 0·4 ca.).

Fig. B. Part of a more elaborate domed structure showing the entrance near the base (x 0·6 ca.).

### PLATE 3

Fig. A. Characters of the head of an adult ♂ of *R. greyi greyi* from the Boat Harbour Creek (x 1·5 ca.).

Fig. B. Right pes of young adult ♂ of the same from the same locality (x 2·4).

Fig. C. Right manus of same individual (x 3·0).

Fig. D. Oblique view of the uncalloused pads of the right manus of an immature ♂ of the same and from the same locality (x 4 ca.).

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[1] Two streams on the Peninsula bear this name; the one flowing west into Investigator Strait and the other south into Backstairs Passage; the latter is indicated.

# NOTES ON THE GENUS SPHAEROTARSUS (ACARINA: SMARIDIDAE)

BY H. H. FINLAYSON

## Summary

The egg, larva and adult male and female of Sphaerotarsus leptopilus, Womersley and Southcott, 1941, are described; the species was hitherto known only from the nymphal stage. The nymph and adults were correlated on morphological characters. The two adults were captured under Eucalypt bark, at Myponga, South Australia, in late December. The female laid eggs in January-February, and these hatched to larvae during April-May. The larvae survived into June. Some observations were made on the biology of the species. Attempts to rear the species beyond the larval sta e were unsuccessful, as no suitable insect host could be found. Aspects of tie biology of the Smarididae are discussed. The systematics of the adults and nymphs of the genus Sphaerotarsus, Womersley, 1936, are revised.

# NOTES ON THE GENUS SPHAEROTARSUS (ACARINA: SMARIDIDAE)

## By R. V. SOUTHCOTT

[Read 12 November 1959]

## SUMMARY

The egg, larva and adult male and female of *Sphaerotarsus leptopilus,* Womersley and Southcott, 1941, are described; the species was hitherto known only from the nymphal stage. The nymph and adults were correlated on morphological characters.

The two adults were captured under Eucalypt bark, at Myponga, South Australia, in late December. The female laid eggs in January-February, and these hatched to larvae during April-May. The larvae survived into June. Some observations were made on the biology of the species. Attempts to rear the species beyond the larval stage were unsuccessful, as no suitable insect host could be found. Aspects of the biology of the Smarididae are discussed.

The systematics of the adults and nymphs of the genus *Sphaerotarsus,* Womersley, 1936, are revised.

## INTRODUCTION

In 1941 Womersley and Southcott reviewed the systematics of the Smarididae of Australia and New Zealand. Among new species described was *Sphaerotarsus leptopilus,* Womersley and Southcott, which was described from a single nymph obtained by sweeping teatree (*Melaleuca halmaturorum,* F. v. M.) along the banks of the Hindmarsh River, Victor Harbor, South Australia. That nymph was distinct from the other described post-larval stages in the narrowness of the dorsal setae (idiosomalae), as well as in other characters.

Some years ago the present writer captured two adult Smaridids at Myponga, South Australia. Those adults were kept in the same tube, and both have been identified finally, on morphology, as the adults of S. *leptopilus.* At the time of capture the male was identified as belonging to *Sphaerotarsus,* this recognition being easy on account of the great enlargement of the fourth tarsus of the male, but the female was not generically identified (if desired this can be done by immobilizing them under one or more cover-glasses on a microscopic slide; they can then be identified after examination with the high power of the microscope for study of the eyes, crista, sensillae and dorsal setae; they suffer no damage if carefully handled).

The female laid eggs in captivity, which hatched to larvae. Larvae belonging to this genus have not been observed hitherto. In a recent monograph (1960) of the systematics of the genera of the superfamily Erythraeoidea the writer drew up a set of generic characters for larval *Sphaerotarsus,* using these larvae.

It is proposed in the present paper to describe the adult male and female, the egg stage, and the larva of *Sphaerotarsus leptopilus.* It is proposed also to describe the experiment in detail and to remark on significant aspects of the
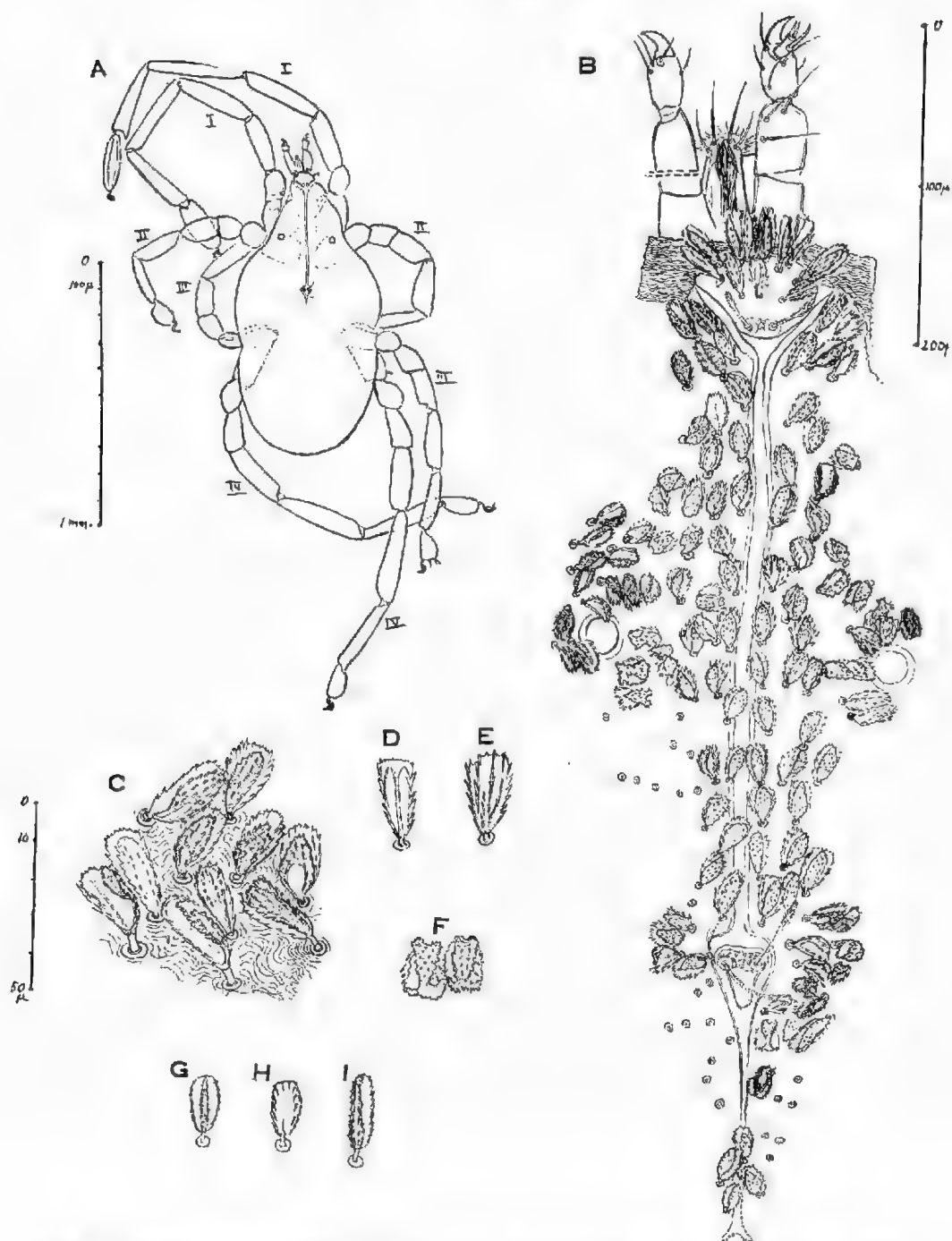
Fig. 1.—*Sphaerotarsus leptopilus* Womersley and Southcott, 1941. A–F Adult female.
A, Entire, dorsal view, setae mostly omitted; B, Mouthparts, crista, eyes and adjacent
setae (ventral view of palp on left); C–F dorsal idiosomal setae, C *in situ*, showing
dorsal and lateral aspects, D, E from below (optical section), F end view; G–I nymph,
dorsal idiosomal setae, G from above, H from below, I a longer seta (Figs. G–I based
on figures of Womersley and Southcott, 1941). (All setae (C–I) to same scale on
left, the same as Fig. 2 A.)

biology of this mite seen in the experiment. Some aspects of the systematics of the genus *Sphaerotarsus* will be discussed, and a revised key given for the separation of the post-larval active stages of the four known species.

## Sphaerotarsus leptopilus Womersley and Southcott, 1941

### Figs. 1-4

Description of adult female (Fig. 1 A-F) (from specimen ACA 1504): Colour orange, with brown setae. Idiosoma of the usual Smaridid form, flattened, elongate, slightly waisted and somewhat pointed anteriorly (i.e. with a short blunted nasus). Idiosomal length 1070μ to tip of nasus, idiosoma 580μ wide where widest.

Crista present, normal, with two sensillary areas. Anterior sensillary area placed in a Y formed by the division of the anterior end of the crista; it carries 12 setae (scobalae), similar to the normal dorsal idiosomalae, 22-30μ long; 7 of these are pigmented, the others unpigmented. Anterior sensillae slender, clavate, with short ciliations along the entire length, these longer over the elongate-spindle-shaped terminal club of the sensilla; anterior sensillae 24μ long. Posterior sensillary area as figured (Fig. 1B); there is a central boss, somewhat nodular, which forms a transverse oblong. The posterior sensillae are set in the central boss; they are clavate, ciliated along their entire length, the terminal club as in the anterior sensillae, elongate-spindle-shaped; posterior sensillae 50μ long. The crista continues some distance beyond the posterior sensillary area, and in the specimen divides terminally as figured into two short divaricating arms. Length of crista behind the centres of the posterior sensillae (PP distance) approximately 175μ.

The standard data* are:

| ASens | PSens | SBa | SBp | ISD | DS |
|-------|-------|-----|-----|-----|-----|
| 24μ | 30μ | 14μ | 17μ | 391μ | 20-28μ |

Eyes one on each side, circular, 30μ across. Eyes placed a little before the midpoint of crista (i.e. the midpoint between the centres of the anterior and posterior cristal sensillae). Distance anterior sensillae-eye centres in the median plane (OAS) 207μ; distance between eye centres and midpoint between posterior cristal sensillae in the median plane (OPS) 184μ.

Dorsal idiosomal setae typically Smaridid in type. They have a strong roughened dorsal flange, strongly convex, lanceolate, about one-half or two-thirds the width of the seta. The dorsal flange carries 4-5 irregular rows of projections (modified ciliations), and frequently the dorsal flange has a basal excavation (these scobalae are similar to those of *Hirstiosoma novaehollandiae* (Womersley, 1936) from New Zealand—see Womersley and Southcott, 1941, p. 71). Dorsal setae 20-28μ long. Some setae are pigmented, others not. Those on the anterior part of the dorsum of the idiosoma and particularly around the crista are mostly unpigmented. Those of the posterior half of the dorsum of the idiosoma and also of the more lateral aspects of the dorsum of the idiosoma are mostly pigmented. The dorsal setae are somewhat longer at the posterior part of the idiosoma.

Venter of idiosoma with bushy strongly ciliated idiosomalae of the usual Smaridid type.

Genitalia normal for female; lacking internal chitinous armature (in the preparation the ventral surface is not clearly seen, owing to its being mounted

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* For these terms and the descriptive terms for the setae used in this paper, see the writer's (1960) monograph on the Erythraeoid genera.

normally, from the density of the dorsal idiosomal setation) (the sex of the specimen also clearly recognizable from the normal tarsus IV).

Legs as figured, of normal Smaridid appearance. Supraonychial tactile setae present (scobalae = tactalae), but not unduly prominent. Leg I 1660μ
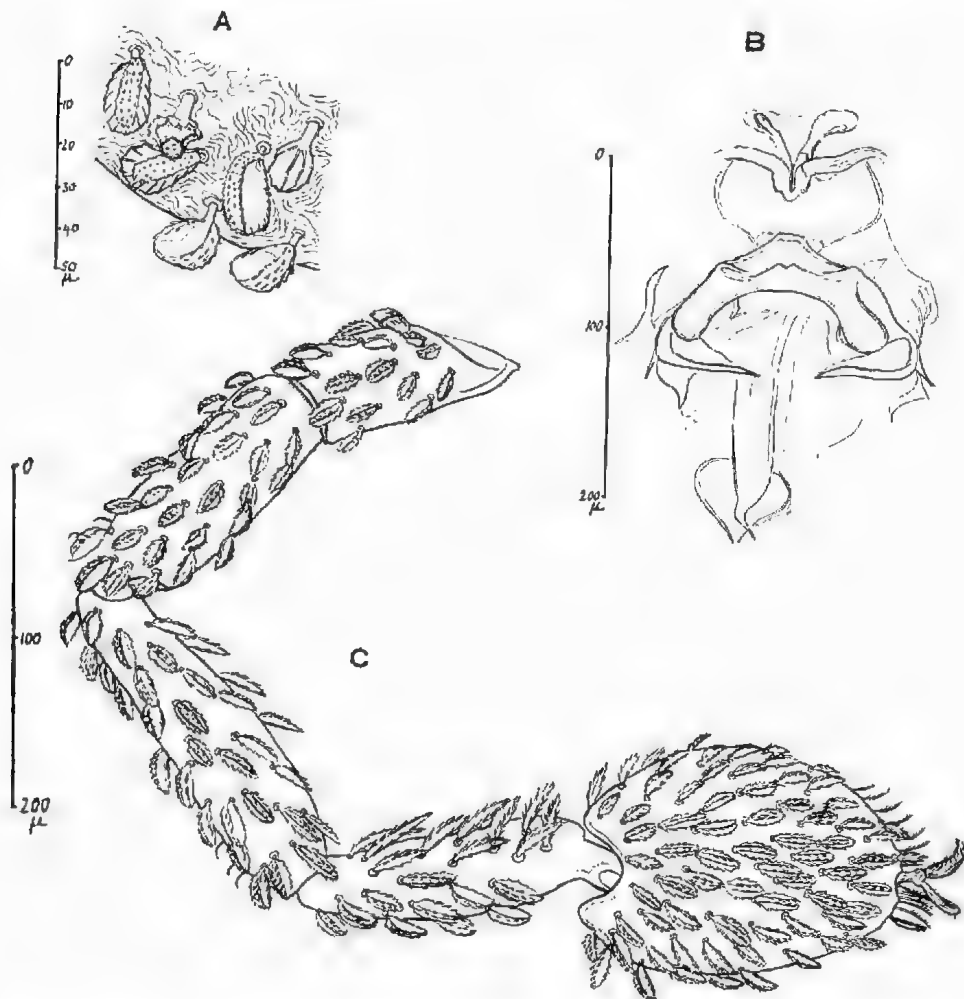


Fig. 2.—*Sphaerotarsus leptopilus* Womersley and Southcott, 1941, adult male. A, Some dorsal setae near the posterior pole of the idiosoma, selected for display of various aspects of the setae, the positions shown being in part due to the distortion of mounting (to same scale as Fig. 1, C-I). B, Internal genitalia from above, to show chitinized parts. C, Left leg IV, detached at the trochanterofemoral joint.

long, II 1020μ, III 1105μ, IV 1460μ (all including coxae and claws). Tarsus I 228μ long (excluding claws and pedicle) by 88μ wide (height not available); tibia I 320μ long. Tarsus IV 135μ long (excluding claws and pedicle) by 63μ high; tibia IV 307μ long.

Tarsal claws 2, normal, ciliated obliquely along their sides. Legs thickly provided with setae of normal type (i.e. scobalae); various other sensory setae are also present on the legs. The anterior tarsi thickly provided distally with short solenoidalae; a number of spinalae ("eupathidies") are present upon the middle segments (telofemora, genua, tibiae) of the legs.

Gnathosoma of normal Smaridid type, with extrusile palpi and mouth-cone, with the normal sleeve or armilla. Palpi normal, as figured; setae of palpi comparatively slender.

*Description of adult male* (Fig. 2 A-C) (from ACA 1505): The general appearance is as described for the female, the most significant points of difference being in the possession of the male internal genital armature, and the secondary sexual character of the greatly enlarged tarsus IV. Other differences are as detailed here.

Idiosomal length 855$\mu$, maximum width 455$\mu$. The standard data are:

| ASens | PSens | SBa | SBp | ISD | DS |
|-------|-------|-----|-----|-----|-----|
| 18$\mu$ | 46$\mu$ | 16$\mu$ | 18$\mu$ | 309$\mu$ | 14-30$\mu$ |

The crista extends only a short distance (32$\mu$) behind the PSens; this is much shorter than in the female.

Eyes one on each side, 27$\mu$ across. OAS 166$\mu$, OPS 143$\mu$; hence the eyes are well anterior to the cristal intersensillary midpoint.

The dorsal idiosomal setae are somewhat more slender and regular than those of the female, and resemble more closely those of the nymphal *S. lepto-pilus*. They are less pigmented than the pigmented female dorsal idiosomalae, and the dorsal flange does not show the basal excavations. The dorsal flange has 4-5 rows of spicules, fairly regular (Fig. 2A). Dorsal setae 14-30$\mu$ long, the opisthosomal dorsal ones being considerably longer than those placed more anteriorly, and in fact the opisthosomal group forms almost a separate group with a reasonably sharp line of differentiation.

Genitalia with the normal internal male apparatus (Fig. 2B).

Legs (except IV) similar to those of female; leg I 1210$\mu$ long, II 730$\mu$, III 790$\mu$, IV 1015$\mu$ (all lengths including coxae and claws). Tarsus I 189$\mu$ long (exclusive of claws and pedicle) by 45$\mu$ high by 56$\mu$ across. Tibia I 215$\mu$ long. Tarsus IV greatly enlarged as usual, ovoid (see Fig. 2C), 173$\mu$ long (excluding claws and pedicle) by 120$\mu$ across. Leg setation as for female.

Gnathosoma as described for female.

*Description of Egg* (from those laid by ACA 1504): Colour orange-brown until the deutovum stage, then becoming deep red; smooth, spheroidal, 190-230$\mu$ long by about 165$\mu$ wide.

*Description of Larva* (Figs. 3, 4) (from ACA 1504L2 principally, including measurements, but description supplemented from ACA 1504L1). Colour, red. Length of idiosoma (unengorged) 325$\mu$, width 230$\mu$; animal 440$\mu$ long to the tip of the cheliceral blades. The idiosoma has the usual rather slender shape of the larval Smarididae.

Dorsal scutum roughly a transverse trapezoid, but somewhat rounded anteriorly, and posteriorly projecting in the median line into an acute point; hence almost stellate in outline (see Fig. 3); with two pairs of scutalae and two pairs of sensillae.
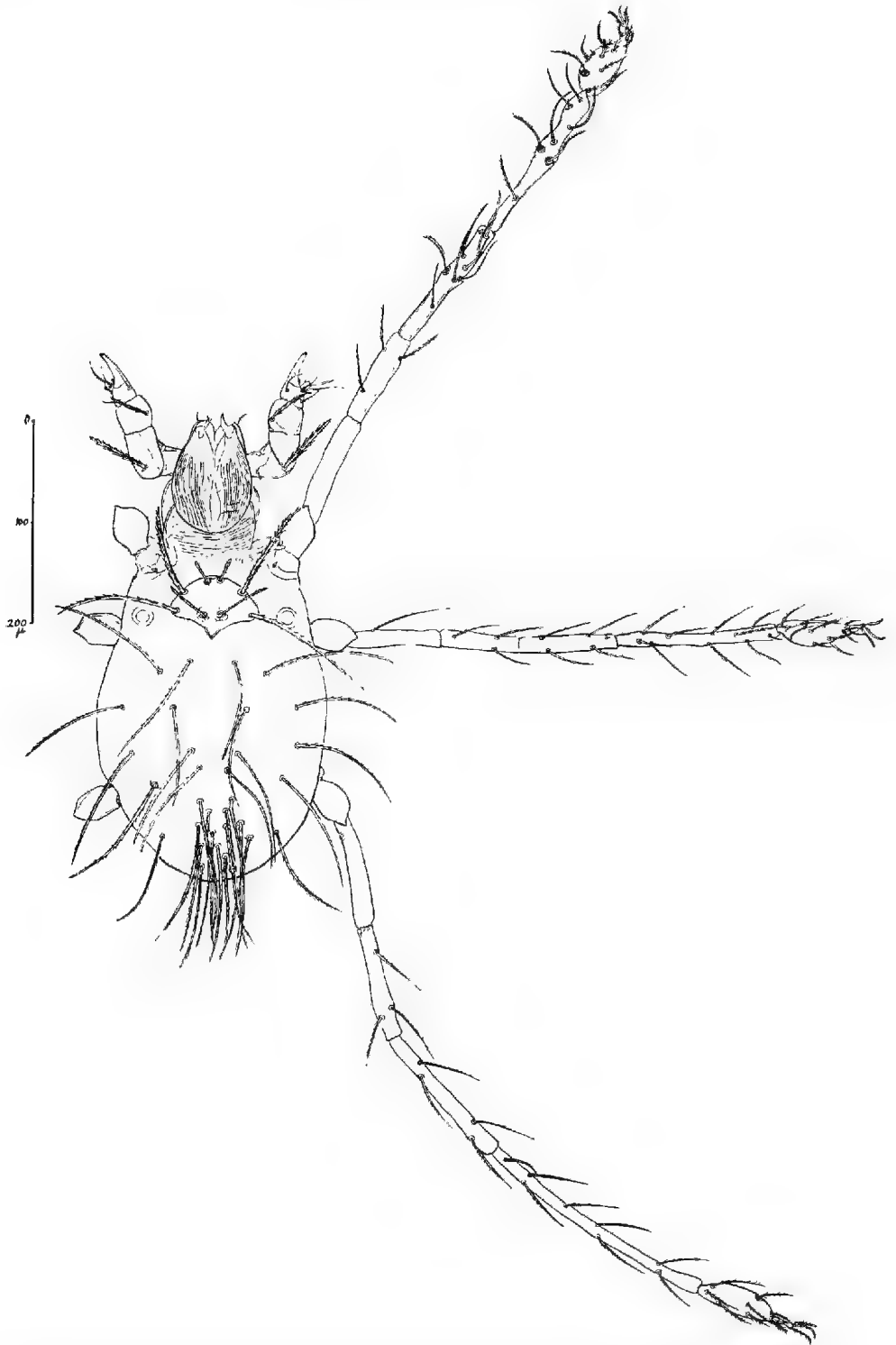
Fig. 3.—*Sphaerotarsus leptopilus* Womersley and Southcott, 1941, larva, dorsal aspect.

The standard data* of the two specimens used in the description are as follow:

| Specimen | ACA1504L2 | ACA1504L1 |
|---|---|---|
| AW | 55 | 52 |
| MW* | — | — |
| PW | 74 | 68 |
| SBa† | 11·5 | 10 |
| SBp | 13 | 14 |
| ASB | 11 | 9 |
| ISD | 35 | 34 |
| L | 68 | 73 |
| W | 81 | 82 |
| A-P | 22 | 16 |
| AL | 91 | 89 |
| ML* | — | — |
| PL | 125 | 108 |
| ASens | 27 | 32 |
| PSens | 60 | 58 |
| ASB/ISD | ·31 | ·26 |
| DS | 104-121 | 95-120 |

* Not available in tetrascutalate genera; listed here for the sake of completeness of Standard Data table.

† Strictly these are negative in *Sphaerotarsus* and *Clipeosoma*.

Scutalae long, tapering, with barb-like ciliations, the setae terminally blunted, AL thicker than PL and with coarser and more outstanding (bractate) ciliations. AL arise behind middle of anterolateral borders of the shield; PL arise inside the lateral angles of the shield. ASens arise well anterior to the AL scutalae in the projecting anterior part of the scutum. ASens with adpressed ciliations, and are slightly thickened in their distal part. PSens arise within the posterior triangular piece of the scutum. PSens longer than ASens, and with adpressed ciliations; PSens parallel-sided except distally where they taper a little.

Eyes one on each side, circular, $12\mu$ across, in the unengorged specimen slightly behind the level of the PL scutalae.

Dorsal idiosomal setae long, strong, but are slender among larval Smarididae,† tapering, pointed, and with adpressed ciliations.

Venter: between coxae I a pair of scobalae (the sternalae), long, pointed, ciliated, $45\mu$ long; in the central area of the venter between coxae II and III a pair of slender tapering scobalae with adpressed ciliations, $50\mu$ long; well behind coxae III, on the ventral opisthosoma, are 2 rows of more robust setae, arranged 4, 2, similar to sternalae, $49$-$65\mu$ long. Each coxa with one seta (coxala): that on I long, pointed, ciliated, $70\mu$ long; on II pointed, slender, with faint adpressed ciliations, and $53\mu$ long; on III more robust, pointed, ciliated, $60\mu$ long.

Legs long and thin: I $650\mu$ long, II $625\mu$, III $790\mu$ (all lengths including coxae and claws). Each trochanter with one seta. Tarsus I thickened, fairly short, $71\mu$ long (excluding claws and pedicle) by $31\mu$ high.

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* See Southcott (1960) for definitions of these.

† These setae are broadened in *Smaris* larval and in *Clipeosoma copiolarum*, Southcott, 1948, but are narrow in *Clipeosoma jupiter*, Southcott, 1960, and in *Pilosoma pluto*, Southcott, 1960, to list larval Erythraeoidea whose position within the Smarididae is undoubted.

On the legs the following is the arrangement of the specialised setae:

| | trichobothrialae (sensillae) | solenoidalae (solenidia) | spinalae (eupathidies) |
|---|---|---|---|
| genu I | 2(+1 int.*) | 2 | 4† |
| genu II | 0 | 0 | 0 |
| genu III | 0 | 0 | 0 |
| tibia I | 6(+1 int.*) | 3 | 0 |
| tibia II | 0 | 1 | 1† |
| tibia III | 0 | 0 | 1‖ |
| tarsus I | 2 | 2 | 0 |
| tarsus II | 0 | 1 | 0 |
| tarsus III | 0 | 0 | 0 |

* int. = intermediate type of sensilla, a modified or transitional scobala.

† These show possibly faint internal solenization, i.e. the development of the helical or banded striae characteristic of the solenoidalae. The solenoidalae and the spinalae may be difficult to distinguish.

Further comment on the chaetotaxy of the legs: On tarsus I there is a compound trichobothrial pit; such is not present on tarsus II or III. Companala present on tarsus I and tibia I, as figured. Vestigiala present on genu I and II as figured. Famulus (famala) present on tarsus I.

Tarsal claws: lateral (neolateral) claws identical, falciform, with long outstanding ventral ciliations and adpressed dorsal ciliations. Neomedian claw (empodium) falciform, more slender than the neolateral, similarly ciliated.

Gnathosoma as figured. Chelae bases ("mandibles") an ovoid mass, with finely punctate chitin, and striated longitudinally (see Fig. 3). Cheliceral blades simple. Galeala (galeal seta) curved, simple, 12μ long. Hypostomal lip present, delicate. Anterolateral hypostomala simple, 12μ long, situated on a chitinous thickening of the hypostome, 23μ from midline and about 22μ behind the tip of the cheliceral fang. Posteromedial hypostomala stronger, pointed, ciliated, 26μ long, arising from a chitinous boss close to the anterolateral hypostomala, but slightly inferior and posteromedial to it.

Palpal setal formula 1, 1, 3, 6. No palpal coxala or trochanterala present. Palpal supracoxala present, 4·5μ long. The claw of the palpal tibia curves anterolaterally, and has a short terminal split, 4μ long, with little or no separation of the two elements. There is no projecting process from the ventral or flexor aspect of the palpal tibial claw (which occurs in *Clipeosoma*). A stout accessory separate conical tooth present ventrally at the base of the tibial claw, 10μ long by 7μ wide, directed anteromedially.

The *nymph* (Fig. 1 G-I) was described in 1941 by Womersley and Southcott. The dorsal setae are illustrated here (by figures based on those of Womersley and Southcott, 1941) for comparison with those of the adults (female in Fig. 1 C-F, male in Fig. 2A, all to same scale).

*Locality.* The adult male (ACA 1505) and the adult female (ACA 1504) were both captured under bark of *Eucalyptus* sp. (not identified specifically, but presumably it was *Euc. cosmophylla* F. v. M., since it was a smooth-barked species) at Myponga, South Australia, on 31st December, 1951, by the writer, in *Eucalyptus baxteri-Eucalyptus cosmophylla* scrubland (the piece of scrubland concerned has since become the Nixon-Skinner Reserve). The larvae were reared from eggs laid by the adult female in captivity (see under biology).

*Biology.* The two adults, taken as recorded, were placed immediately in a dry tube, sealed with a cork. The only additional contents were water drop-

lets, which were given periodically for the mites to drink. The following account of the remainder of the experiment is from my notes (somewhat contracted and rephrased).

6th January, 1952. Mites are well. No eggs present. More water added.

27th January, 1952. The larger (female) mite was lying on her back, rather shrunken (due to dehydration), clasping the apparently dead male. There were no eggs in the tube. Further water was added.

24th February. The male unaltered, dead, dry. The female is well but shrunken. "There is a chain of about 21 brown smooth spheroidal eggs in the tube, which have obviously been laid by the larger Smaridid" (this was the first occasion on which the writer had ever seen eggs laid by any Smaridid mite, despite many attempts at rearing them over a number of years).

2nd March. The large (female) Smaridid feeble, shrunken, mostly lying on her back, but waving her legs about a good deal. When righted by my help the mite "walks a bit". The mite soon managed to get itself stuck in the water, but on turning around, drank. It remained in an attitude of drinking, and in about 5-10 minutes it had regained its normal form and was quite plump again. At this stage it managed to get itself stuck in the water again. I took it out of the tube to dry (this would have been done by placing it on a piece of blotting paper with a fine sable brush). "After an initial few minutes of incoordination and possibly of flexor spasms it ran quite actively." It was then placed in a clean fresh tube in an attempt to stop its fouling the eggs with mould. The dried male was removed from the tube of the eggs.

16th March. The eggs are beginning to sprout mould filaments, so no further water is to be added. The eggs are quite plump.

The adult female is lying on her back "in a tetanic state". Legs I are extended, the others are flexed. Occasionally one leg moves, and then flicks back to the flexed position. Still under observation some minutes later the mite flexed its left leg I to a right angle at the femorotibial joint, simultaneously extending right leg III, with the other legs remaining semiflexed, all this while the female was lying on her back. Water was added to the tube. (Note: no food was proffered to the adult mites at any stage, and the only possibility of their getting any food while in captivity lay in their attacking each other, or the eggs after oviposition. Such behaviour, however, has not up to the present been observed in any Smarididae or other Erythraeoidea.)

23rd March. The eggs appear possibly very slightly shrunken. The other tube containing the adult female is wet. The adult female lies immobile, and is beginning to sprout mould filaments. In her mouthparts a large amber globule of liquid is present. It was concluded she was dead, decomposing and mouldy. She remained thus, and was finally mounted through lactic acid to polyvinyl alcohol medium on 8th May, 1952.

On 25th April, 1952, one egg was observed to be in the deutovum stage, and of the others it was recorded they "nearly all look plump and healthy".

On 5th May (the next observation) six larvae had hatched, the other eggs remaining unhatched and appearing healthy.

On 7th May 11 larvae were present in the tube. Two were removed for mounting and study (ACA 1504 L1 and L2)

On 8th May the larvae in the tube appeared well. Two days later "about 3" of the larvae were stated to be "dead or look very poorly". Insects obtained from Heywood Park, South Australia, were added to the tube to serve as possible hosts for the larvae, during the afternoon and evening. Among insects offered initially were various small Diptera, Hymenoptera and Homoptera, including an unidentified Delphacid, as well as Psylloidea of the genera *Spon-*
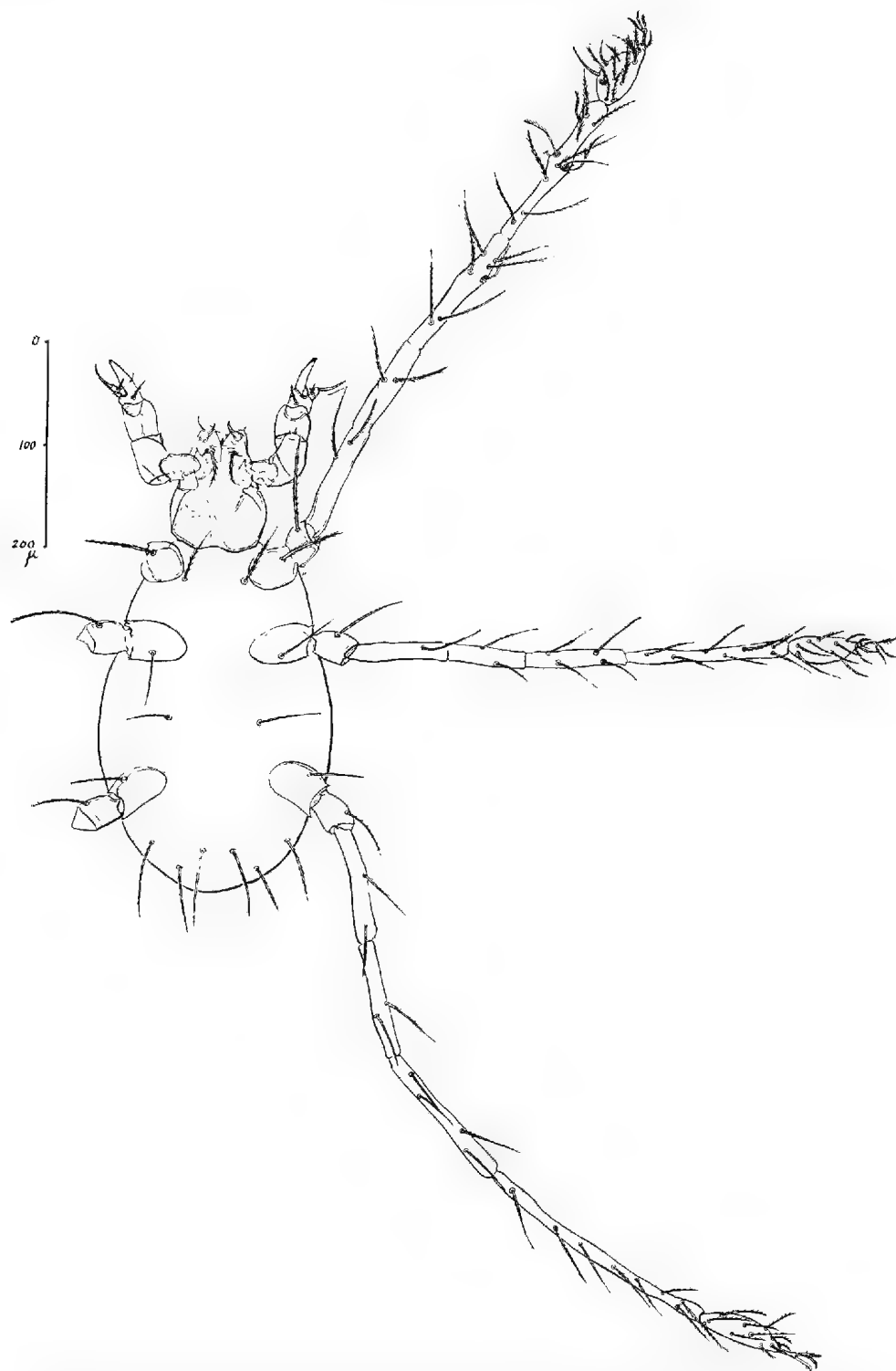
Fig. 4.—*Sphaerotarsus leptopilus* Womersley and Southcott, 1941, larva, ventral aspect.

*dyliaspis, Eucalyptolyma* and *Cardiaspina.* No parasitization was observed with any of these living insects, and the larval mites appeared to take only a momentary interest in them (in general if a suitable insect host is provided for them larval Erythraeoidea will attack at once, or within a very few minutes). Later I added a number of *Troctes* sp. or spp. (Psocoptera) from under bark of *Eucalyptus camaldulensis*, from East Parklands, Adelaide (10th May, 1952). These Psocoptera were added since the only host that has been discovered so far for an undoubted* larva of the Smarididae is this genus of Psocoptera (recorded by Womersley and Southcott (1941)) for the larva of *Smaris prominens* (Banks, 1916). Since then the writer has seen other specimens of larval *Smaris* from *Troctes* from north Queensland (see below). (These insects have been identified on the advice of various specialists, to whom a number of insects have been submitted, notably Mr. K. L. Taylor of the Division of Entomology, C.S.I.R.O., for the Psylloidea, and Dr. J. V. Pearman, of the British Museum, for the Psocoptera.)

The larval *Sphaerotarsus*, however, took no interest in the *Troctes*.

On 12th May, 1952, 6 eggs remained unhatched in the tube. Some of the insects added earlier remained alive. Further living insects were added to the tube on 12th and 13th May: further psyllids, a fly, an aphis, and although the larval mites walked over the insects they made no attempt to parasitize them.

On 14th May only one larva remained alive. Several eggs remained in the tube, being recorded as "ruby red". On 19th May one larva was running around in the tube, and on 20th May the tube contained two living larvae. Only four eggs now remained unhatched. On 26th May four larvae were active and well in the tube. The only insects remaining alive were the *Troctes*, but again no attempt to parasitize them by the mites was observed. Further insects were proffered to the larval mites, but none was accepted as a host.

On 1st June, 1952, one larva remained in the tube. No further record was made of this experiment until 1st August, 1952, when all the contents of the tubes were dead and dry.

In summary, therefore, the eggs are laid in late summer (January-February) and hatch out in the late autumn or early winter (April-May). The egg period lasts, therefore, approximately three months.

## REMARKS ON BIOLOGY

The only other undoubted Smaridid upon which any substantial observations have been made upon the life history is *Smaris prominens*. The principal details of the life history of that species were given by Womersley and Southcott (1941). In a subsequent experiment done by the writer two adult females of *S. prominens* (number ACA 1506), captured from under bark of *Eucalyptus leucoxylon*, Heywood Park, Adelaide, South Australia, on 16th February, 1952, were placed in a tube. One had died by the following day. The other remained well and laid about 17 eggs in captivity, between 2nd and 16th March. The eggs were dark brown, smooth, spheroidal, 170-205μ long by 100-125μ across. These eggs did not hatch, possibly due to an infection with mould. It is known from the earlier field observations that the larva is parasitic upon *Troctes* in April-May in the Adelaide region, hence it may be concluded that the egg stage lasts about 1-3 months.

It may be remarked also that the writer has captured two further larvae of *S. prominens* at Kaban, north Queensland (Map reference Palmerston 1:63360

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* The status of *Phanolophus* as a Smaridid is not absolutely certain (see Southcott, 1960). The larva of this monotypic genus, *P. oedipidarum*, is an ectoparasite of locusts in the Mediterranean region and in central Europe.

269982-270981), 24th August, 1944, specimens ACA 1633 A, B, parasitic upon the Psocoptera *Troctes* sp. (nymph) (Troctidae) (A 190) and a nymph (A 191), probably of *Pteroxanium kelloggi* (Rib.) (Lepidopsocidae) ( = *Tasmanopsocus litoralis* Hickman) (identifications by the kindness of Dr. J. V. Pearman, British Museum; Dr. Pearman has given the foregoing synonymy and commented that in the case of A 191 "Identification based on what is discernible [in the slide mount]; some distinctive features obliterated"; pers. comm., *in lit.*, 1958).

In general it may be concluded that the life histories of the two Smaridids studied, *Smaris prominens* and *Sphaerotarsus leptopilus*, are broadly comparable, with (in southern Australia) the features of summer oviposition and the larval stage in autumn-winter.

The attempt to find a suitable host for the larval *Sphaerotarsus* by trial and error was unsuccessful, and the larvae have never been captured parasitic (or at all) in the field. It is possible that they have a restricted insect or other arthropod host. The hosts offered had not come from the locality where the species has been captured. The recorded range for the species is the southern end of the Mt. Lofty Ranges, the adults having been captured in *Eucalyptus baxteri-Eucalyptus cosmophylla* forest. It should be noted that the genus *Sphaerotarsus* is found fairly widely in Australia, so far having been recorded (with a total of four species) from South Australia, Victoria and New South Wales (see Womersley and Southcott, 1941).

## REMARKS ON THE SYSTEMATICS OF *SPHAEROTARSUS*

The study of the adults of *S. leptopilus* allows some comment on the classification of the adults and nymphs of the genus. The writer sees no reason to doubt that the adults described are conspecific with each other and with the nymph of *S. leptopilus* described earlier. The dorsal idiosomalae correspond to each other reasonably well, allowing for the tendency to elongation which occurs in the Erythraeoid nymphal idiosomalae. The variation between the setae of the male and the female described should be noted, both in the dorsal idiosomal setae and in the cristal sensillae.

In the key of Womersley and Southcott (1941, p. 78) the nymph of *S. leptopilus* was separated off in the first caption by "Posterior sensillary setae 1·5 × as long as anterior" (i.e. the ASens/PSens ratio of ·67) together with other characters. The discovery of the adult stage with the ASens/Pens ratio of 24/47 = ·51 (female) and 18/46 = ·39 (male) makes some alteration to the key given necessary. At the present time, pending a full review of the genus in Australia, it is proposed that the following will serve to separate the adults and nymphs of this purely Australian genus:

1   Posterior cristal sensillae up to 2·5 × as long as anterior.................2
    Posterior cristal sensillae 3·0 × as long as anterior, or more............4

2   The dorsal flange of the dorsal idiosomal setae in outline a narrow triangle, apex pointing distally, and with "cross-bars" running out laterally; in the nymph the dorsal setae are similar, and broad.................................
    *S. womersleyi* Southcott 1946 ( = *S. ripicolus* Womersley 1936, *nom. invalid.*)

    The dorsal flange of the dorsal idiosomal seta not tapering distally, and without "cross-bars" running out laterally. In the adult the dorsal flange is rugose, and either broad-linear or elongate-oval in outline; in the female basal excavations may be present; in the nymph the setae elongate and slender.......................*S. leptopilus* Womersley and Southcott 1941.

3   As in (3) of the key of Womersley and Southcott (1941, p. 78) for *S. allmani* Womersley 1936 and *S. claviger* Womersley and Southcott 1941.

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* Contains a full bibliography of the family.

# A CONSIDERATION OF THE SPECIES PREVIOUSLY INCLUDED WITHIN HELIPTERUM ALBICANS (A. CUNN.) DC.

*BY PAUL G. WILSON*

## Summary

**A** key to and description of the species, varieties, and forms previously included under Helipterum albicans is given. One new species (H. saxatile), and three new infraspecific taxa, all from Central or South-eastern Australia are described. One specific (H. molle), and three infraspecific combinations are made. All specimens cited from the following herbaria have been seen: State Herbarium of South Australia (AD); Waite Agricultural Research Institute, Adelaide (ADW); Botanic Museum and Herbarium, Brisbane (BRI) ; C.S.I.R.O. Div. of Plant Industry, Canberra (CANB) ; Snowy Mountains Hydro-Electric Authority, Soil Conservation Section (COOMA) ; Gauba Herbarium, Canberra (GAUBA) ; Geneva, De Candolle Herbarium (G-DC) ; University of Tasmania (HO) ; Royal Botanic Gardens, Kew (K) ; National Herbarium of Victoria (MEL); National Herbarium of New South Wales (NSW); Herbarium of Northern Territory, Alice Springs (NT) ; State Herbarium of Western Australia (PERTH) ; Department of Botany, University of Sydney (SYD) .

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*(Communicated by Hj. Eichler)*

[Read 12 November 1959]

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One specific (*H. molle*), and three infraspecific combinations are made.

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## INTRODUCTION

De Candolle in his Prodromus 6:215 (1937), created under the genus *Helipterum* a Section *Leucochrysum*, in which he placed four species, *H. incanum* (Hook.) DC., *H. bicolorum* A. Cunn. ex DC., *H. albicans* (A. Cunn.) DC., and *H. cotula* (Benth.) DC. All these except for *H. cotula* are characterised among other points by having stipitate involucral bracts. *H. cotula* is anomalous as its bracts have broad short bases.

Mueller in 1859 united the first three and *H. brachyrrhynchum* under *H. incanum* but recognized seven varieties, some of which I have retained. Bentham (and later authors) followed Mueller in recognizing only one species, he also included within it *Helichrysum molle* DC., a species placed by De Candolle in *Helichrysum* Section *Blepharolepis*, but it differs from the other members of that section in having a plumose, not barbate, pappus, and rightly belongs in the section *Leucochrysum* of *Helipterum*. Subsequently F. von Mueller, R. Tate, and later J. M. Black, included a further distinct plant within *incanum*, which I am describing as a new species, *H. saxatile*. This species is apparently more closely related to *Helichrysum elatum* DC., from which it differs among other points in having a more plumose pappus.

George Don in 1938 placed *H. incanum* in David Don's genus *Aphelexis* which as defined by D. Don is a purely South African group and possesses a receptacle with "rigid, pointed paleae", in *H. incanum* the receptacle is naked.

The variation between the taxa within *Helipterum albicans* appears from the herbarium material to be continuous (except in the variety *graminifolium* which is at the moment represented by only a few collections), and it is ap-

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[*] State Herbarium of South Australia, Adelaide.

parent that, except for the one variety noted, each taxon intergrades with one or more of the other taxa, although, possibly due to geographical separation, intermediates in all directions have not yet been found.

Two additional species have been described since De Candolle's Prodromus which are similar in capitula characters, *Helipterum stipitatum* F v M. and *H. fitzgibbonii* F v M. From material seen these two species appear to be invariable and show no signs of hybridization with any other species. *H. stipitatum* is easily distinguished by its outer involucral bracts which are narrow and stipe-like; *H. fitzgibbonii* by its glandular-hairy (not woolly) indumentum, and its narrowly lanceolate, ciliate, outer involucral bracts.

## Key to the "Helipterum albicans" group.

1. Leaves broadly oblong to obovate, sessile, margin wrinkled; plant somewhat shrubby.
   *H. saxatile*
1. Leaves filiform to narrowly oblong or oblanceolate, or if obovate then petiolate and with a smooth margin; plants at most with a woody perennial branching base.
   2. Plant annual; achene densely and prominently papillose; intermediate bracts broadly ovate to suborbicular, pale yellow; leaves broadly linear to oblong or oblanceolate.
      *H. molle*
   2. Plant perennial (or if annual then with narrowly ovate bracts and filiform to narrowly linear leaves); achene smooth to coarsely papillose; intermediate bracts from narrowly lanceolate to ovate, or if deltoid then with red streaks.
      3. Leaves obovate or oblanceolate, thick, plant densely lanuginose.
         *H. albicans* subsp. *alpinum*
      3. Leaves filiform to narrowly oblong or narrowly oblanceolate, thin. Indumentum variable.
         4. Leaves with the upper surface glabrous, filiform, congested.
            *H. albicans* subsp. *albicans* var. *graminifolium*
         4. Leaves lanate on both surfaces, filiform to linear, narrowly oblong, or oblanceolate, congested or somewhat scattered.
            5. Inner involucral bracts white.
               6. Involucral bracts with the lamina (9-)10-15 mm. long, elliptic or lanceolate (rarely obovate or ovate), leaves filiform to linear; disc pale greenish yellow. Tasmania and Grampians of Victoria.
                  7. Intermediate involucral bracts with lamina elliptic, usually narrowly so, rarely narrowly obovate or narrowly ovate, obtuse.
                     subsp. *albicans* var. *incanum* f. *incanum*.
                  7. Intermediate involucral bracts lanceolate, acute or acuminate.
                     subsp. *albicans* var. *incanum* f. *grampianum*
               6. Involucral bracts with the lamina from 5 to 10 mm. long, oblong to ovate (or rarely elliptic), obtuse to acute, disc yellow. Leaves filiform to linear or narrowly oblanceolate. Mainland plant.
                  subsp. *albicans* var. *incanum* f. *purpureo-album*
            5. Inner involucral bracts yellow.
               8. Intermediate involucral bracts ovate to oblong, obtuse to acute. Outer bracts pale to dark brown; leaves filiform to linear; perennial (or occasionally annual?).
                  subsp. *albicans* var. *albicans*
               8. Intermediate involucral bracts broadly ovate to deltoid or orbicular, apex rounded to acute.
                  9. Outer bracts dark brown or purple, often streaked, central ones with the lamina broadly ovate to deltoid; leaves linear; perennial. subsp. *albicans* var. *buffaloensis*
                  9. Outer bracts colourless to pale brown, central ones with the lamina broadly ovate to suborbicular, obtuse to rounded; leaves broadly linear to oblong or oblanceolate; annual.
                     *H. molle*

Fig. 1.—*Helipterum saxatile* P. G. Wils. (Ising s.n. Evelyn Downs): 1, habit; 2, corolla; 3, achene; 4, an intermediate bract.

**Helipterum saxatile** *P. G. Wilson* sp. nov.; *H. albicans* (A. Cunn.)DC. affinis sed foliis latis, marginibus undulatis pedunculis brevis, bracteis anguste ellipticis differt.

[*H. stipitatum* F v M. var., Mueller, Fragm. 10: 109 (1877).]

[*H. incanum* (non (Hook.)DC.)—F. v. Mueller, Trans. Roy. Soc. S. Austral. 3: 134 (1880); Tate, Fl. Extratrop. S. Austral. 125 (1890), and in Rep. Horn Exped. Bot. 3: 165 (1896).]

[*H. albicans* (non (A. Cunn.)DC.)—J. M. Black, Fl. S. Austral. 624 (1929), p.p., and 2nd ed. 901 (1957) p.p.]

[*H. incanum* (Hook.)DC. var. *irvineae* F v M. in sched.]—Figs. 1, 3, 7(1).

Herba perennis fruticulosa dense ramosa ad 40 cm alta; rami inferiores lignosi ad 1·5 cm crassi. Caules annotinorum dense albido-lanuginosi ad 15 cm longi, 2 mm lati. Folia sessilia oblonga vel anguste obovata, apice obtuso vel acuminato, apiculato, ad 3·5 cm longa, 0·7 (−1·1) cm lata, marginibus undulatis, utrinque albido-lanata. Pedunculus terminalis, 1-8 cm longus, dense lanuginosus pauci bracteatus; bracteae lineares vel filiformes 2-5 mm longae. Involucrum hemisphericum ad 2 cm latum, exterius album vel pallido-rubrum, interius album. Bracteae laminarum basibus lanatis, exteriores sessiles anguste oblongae, acutae ad 2 mm longae, interiores stipitatae, stipite viridi plano-subulato 4-5 mm longo, lamina elliptica c. 6 mm longa apice obtuso basi anguste cuneata; bractea intimae stipite lineari viridi c. 6 mm longi, lamina ovata c. 3 mm longa. Receptaculum planum c. 4 mm latum. Flosculi homogami; corolla tenuis 6-8 mm longa, fauce vix tubo latiore, lobis acutis c. 0·8 mm longis; antherae c. 2·5 mm longae basi setiferae. Styli rami c. 2 mm longi, apice rotundati. Achaenia glabra, dense et minute papillosa, c. 2 mm longa. Pappi setae 15-20, albae, brevissime plumosae, c. 6 mm longae.

Distribution—Central Australia, northern South Australia, eastern Queensland and north-eastern New South Wales.
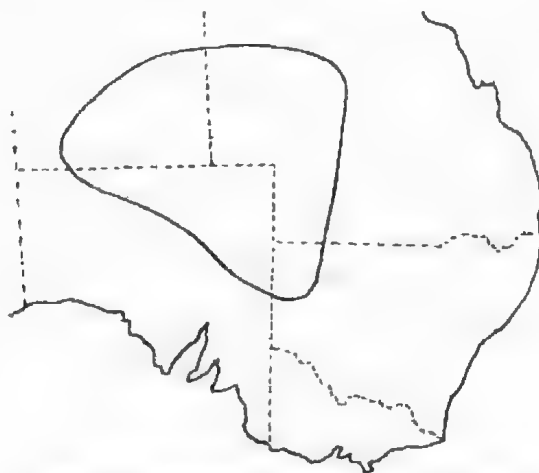


Fig. 2.—Distribution of *Helipterum saxatile*.

NORTHERN TERRITORY. Arltunga or Claraville, *M. L. Benda* (AD); near Harts Range Police Depot, 12 Sept. 1956, *M. Lazarides* 5976 (CANB); Mt. Sonder, [1894], *R. Tate* (AD); Mt. Gillen, 9 Aug. 1936, *J. B. Cleland* (AD); Alice Springs-Charlotte Waters, 1875, *C. Giles* (MEL); Alice Springs-Standley Chasm, 11 Oct. 1950, *Ganba* 616 (GAUBA); nr. Bond Springs, 22 Apr. 1954, *R. E. Winkworth* 201 (NT); Macdonnell Range-Queensland border, 1882, *E. Flint* (MEL); Gosse Range, 28 Aug. 1956, *J. B. Cleland* (AD); near Hermannsburg,

24 Aug. 1956, *G. Chippendale* 2632 (NT holotype, NSW iso, CANB iso) and 22 Aug. 1956, 2551 (NT); *ibid.*, 26 Aug. 1956, *G. Chippendale* 2704 (AD); *ibid.*, 13 Aug. 1929, *J. B. Cleland* 23 (AD); nr. Upilla Gorge [McMilla Cr.], [1894], *R. Tate* (NSW); nr. Deep Well Siding, 3 Sept. 1956, *C. Chippendale* 2716 (BRI, NSW, CANB); Tobermorey Boomerang paddock, 9 Sept. 1954, *G. Chippendale* 229 (BRI, AD); Finke, *R., H. Kempe* 409 (MEL); *ibid.*, 1879, *H. Kempe* 61 (MEL); Horse Shoe Bend (Mt. Engoordina), 24 Aug. 1931, *E. H. Ising* (AD); *ibid., H. Kempe s.n.* (AD); Henbury, 3 June 1935, *J. B. Cleland* (AD); towards Mt. Olga [1873], *W. C. Gosse* (MEL); Lilla Creek, near Old Crown, 17 Aug. 1955, *D. Cutley* 1915 (NSW, NT, CANB); N.W. Australia, 1903, *H. Basedow* 126 and 443 (NSW).

Queensland. Duchess Township, 2 Sept. 1953, *M. Lazarides* 4030 (CANB).

New South Wales. Barrier Range, Sept. 1889, *J. F. Irvine* (AD); Corona Station, Silverton, Sept. 1889 and 1890, *J. F. Irvine* (MEL); m. Silverton, Aug. 1889, *J. F. Irvine* (NSW); Mt. Brown, *W. Bauerlen* 315 (MEL).

South Australia. Evelyn Downs, Oodnadatta, 16 Sept. 1955, *E. H. Ising* 3836 (NSW, AD); *ibid.*, 16 Sept. 1955, *E. H. Ising* (AD 95923004); *ibid.*, 3 Sept. 1955, *E. H. Ising*, 3832 (AD); *ibid.*, 17 Sept. 1952, *E. H. Ising* (AD); *ibid.*, Oct. 1950, *E. H. Ising* (AD); *ibid.*, 26 Aug. 1954, *E. H. Ising* 3739 (AD); *ibid.*, 16 Sept. 1955, *E. H. Ising* 3991 (AD); *ibid.*, 22 Oct. 1955, *E. H. Ising* (AD); Mt. Clarence, *L. S. Francis* (AD); Upper Arkaringa Valley, 19 May 1891, *R. Helms* (AD, MEL, NSW, K); Interior of South Australia, *W. C. Gosse* 101 and 198 (K).

This plant is present in many herbaria under the name of *Helipterum incanum* var. *irvineae* F v M., Mueller having thus labelled specimens sent to him by Mrs. Jemima F. Irvine from near Silverton, south of the Barrier Ranges, N.S.W., which he received in 1889 and 1890. In the Melbourne Herbarium there is a specimen of this plant collected by William Christic Gosse in 1873 "towards Mt. Olga", attached is a lengthy manuscript written by Mueller in which he describes it as a new species of *Helipterum* and states that he is naming it after Reynolds [Thomas Reynolds, Commissioner of Crown Lands 1872-73 and previously Treasurer and Premier of South Australia.] However, neither the name *"irvineae"* nor *"reynoldsii"* appear to have been published. In 1877 (Fragm. 10: 109) Mueller remarked on a plant collected between Alice Springs and Charlotte Waters which he considered to be a variety of *Helipterum stipitatum* having, however, lanuginose-tomentose lanceolate leaves, lanceolate not subulate outer involucral bracts, and white inner bracts, apparently being intermediate between *Helichrysum* and *Helipterum*. There is a corresponding specimen of *H. saxatile* in the Melbourne Herbarium collected by Christopher Giles in 1875 between Alice Springs and Charlotte Waters, on which Mueller has made similar notes, presumably therefore his remarks in the Fragmenta were based on this collection. In 1890 Mueller, in passing, makes another note on this species [Trans. Roy. Soc. S. Austral., 13: 170 (1890)] in which he refers to it as "the broader leaved form of *H. incanum*, with the usual lanuginous vestiture, [which] penetrates also quite as far as the Tropic of Capricorn into Central Australia". It is, I feel, fairly certain that although Mueller several times considered describing this plant as a new variety or species, he never finally did so. That both Ralph Tate and J. M. Black also noted this plant and confused it with *H. albicans* is indicated in the literature cited above and was made apparent by a study of the specimens in the herbaria of these authors (AD).

*H. saxatile* appears, as noted by Mueller, to be intermediate between *Helichrysum* and *Helipterum*. It is probably closely allied to *Helichrysum elatum* A. Cunn. ex DC. and *Helichrysum lanuginosum* A. Cunn. ex DC., both of which have similar involucral bracts and florets, but differ in having smooth achenes and pappus bristles only shortly denticulate. In *H. saxatile* the pappus bristles are nearer to those of *H. albicans*, i.e., subplumose, however, the change from

the denticulate bristle of *Helichrysum lanuginosum* to the sub-plumose bristle of *Helipterum albicans* is not sharp and certainly not in itself a natural basis for generic distinction. Although *H. saxatile* is not closely related to *H. albicans*, they are considered together in this paper because of their constant association and confusion in previous works.

The name *saxatile* is given to the plant because of its growing in stony habitats.

I should like to acknowledge my thanks to Mr. E. H. Ising, who has collected both *H. saxatile* and *H. molle* fairly widely in South Australia; he felt sure that these were two distinct species, drew my attention to the confusion, and gave his collections and extensive notes to me for study.

**Helipterum albicans** (*A. Cunn.*)*DC.* Prod., 6: 215 (1838); Ewart, Fl. Vict., 1130 (1931).

*Elichrysum albicans* A. Cunn. in Field, Geog. Mem. N.S.W. 359 (1825). Type, Forest Land, Cox's River, 9 Oct. 1822, A. Cunningham 71 (holo K, iso? MEL).

*Argyrocome albicans* (A. Cunn.) O. Kuntze, Rev. Gen. Pl. 1: 308 (1891).

[*Helipterum incanum* (non (Hook.)DC. sensu stricto) — Hooker, Icones Pl.t.318 (1841) as to specimens cited; Bentham, Fl. Austral., 3: 643 (1867); Bailey, Syn. Queensl. Fl. 251 (1883); Moore, Cens. Pl. N.S.W. 38 (1884); Mueller, Key Syst. Vict. Pl. 33 (1885); Mueller, Sec. Syst. Cens. Austral. Pl. 136 (1889); Woolls, Pl. Indig. and Nat. Neighb. Syd. 33 (1891); Bailey, Queensl. Fl. 831 (1900); Dixon, Pl. N.S.W. 192 (1906); Bailey, Compreh. Cat. Queensl. Pl. 266 (1913?); Sulman, Wild. Fl. N.S.W. 2: 73 (1914); Maiden and Betche, Cens. N.S.W. Pl. 203 (1916); Field Nat. Cl. Vict., Cens. Pl. Vict. 68 (1923).]

A perennial herb (or occasionally annual ?), 12-45 cm high, base branched and often woody, sometimes decumbent, the older stems often covered with brown scarious persistent leaf bases. Young stems sparsely to densely lanate,
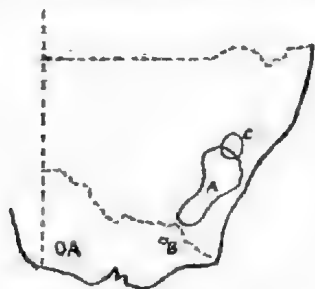


Fig. 3.—A, Distribution of *Helipterum albicans* f. *purpureo-album*; B, var. *buffaloensis*; C, var. *graminifolium*.
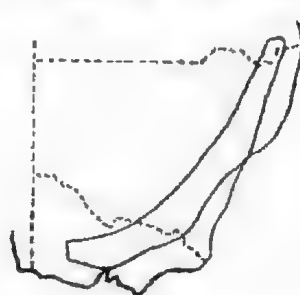
Fig. 4.—Distribution of *Helipterum albicans* var. *albicans*.

erect, leafy. Leaves more or less lanate at least below, scattered or congested on the younger portions of the stems, filiform with revolute lamina, to linear, narrowly oblong, or obovate, the base clasping, 2·5-10 cm long, 0·1-1 cm wide. Peduncle terminal, sparsely to densely lanate, 5-20 cm long, with a few scattered scarious linear to filiform bracts. Capitulum solitary, terminal. Involucre 2-3 (-5) cm wide, hemispherical, reflexed in fruit. Outer bracts sessile, oblong to ovate, with the apex obtuse to acute, intermediate ones stipitate with the lamina deltoid to narrowly elliptic, apex rounded to acute, base woolly ciliate, truncate

to narrowly cuneate, 6-10 (-15) mm long, 2-5-4 (-6) mm wide, stipe subulate, minutely papillose on the outer surface, to 6 mm long; innermost bracts with a short lamina and a flattened scariously winged stipe. Outer bracts purple, brown, pale yellow, or colourless, fading with age, inner bracts yellow or white. Disc pale greenish-yellow to bright yellow. Florets homogamous. Corolla sparsely papillose on the outside c. 5 mm long, with the tube 2-3 mm long, throat narrowly campanulate 2-3 mm long, lobes ovate to lanceolate 0·5-1 mm long. Achene ± obovoid obscurely four angled, curved, smooth to verruculose, 2-3 mm long. Pappus bristles 14-20, sub-plumose except at base, free, more or less equalling the corolla in length.

subsp. albicans.

Leaves filiform to linear. Corolla c. 5 mm long. Achene ± smooth to verruculose or papillose.

var. albicans.

*H. incanum* (Hook.)DC. var. *flavidiceps* F. v. M. Rep. Babbage's Exped. 14 (1859). Type, "Subalpine plains on the Snowy River", F. v. Mueller (iso K, holo MEL).

*H. incanum* var. *auriceps* F. v. M. l.c.

*H. incanum* var. *filifolium* F. v. M. l.c. Type, Station Peak, You Yangs Mts., nr. Geelong, Victoria, F. v. Mueller (iso K, holo MEL).

[*H. incanum* (A. Cunn.)DC. var. *auriceps* (F. v. M.) Ewart, Fl. Vict. 1130 (1931) (combination not validly published).]—Figs. 4, 7(3).

Plant perennial (or occasionally annual?). Leaves scattered or congested, filiform to linear, lanate. Intermediate involucral bracts with the lamina ovate to oblong or lanceolate, yellow, 5-8 (-10) mm long, outer bracts pale to dark brown. Disc yellow. Achene smooth to coarsely verruculose.

Distribution. South-east Queensland, eastern New South Wales, central and eastern Victoria.

QUEENSLAND. Canal Creek, 1882, *Hartmann* 769 (MEL); Burnet, *C. Haly* (MEL). Condamine, *anon.* 354 (MEL); Ramsay, *J. Margins* (BRI); Warwick, Silverwood, 24 Aug. 1934, *S. L. Everist* (BRI); *ibid.*, Sept. 1922, *C. T. White* 1755 (BRI); The Summit, 22 Nov. 1946, *Everist and Webb* 1332 (CANB); Stanthorpe, *T. A. Bernays* (BRI); *ibid.*, *Davidson* 13 (BRI); *ibid.*, *F. M. Bailey* (BRI); *ibid.*, Oct. 1916, *H. Wright* (BRI); Upper Macintyre R., Oct. 1887, *A. Butler* (MEL); Severn R., 1873, *Hartmann* 46 (MEL, BRI).

NEW SOUTH WALES. Clarence R., 1872, *Wilcox* (MEL); Maryland, Mar. 1885, *E. Hickey* 210 (MEL); Wilson's Downfall, Nov. 1904, *J. L. Boorman* (NSW); Boonoo Boonoo-Wilson's Downfall 9 Jan. 1956, *M. Gray* 3751 (CANB); Tenterfield, 22 May 1947, *E. F. Constable* (NSW); *ibid.*, Nov. 1874, *anon.* (MEL); Open Plains, New England, *anon.* 30 (MEL); New England, 2000 ft., *C. Stuart* 55 (MEL); New England, 1886, *R. Collie* (MEL); Emmaville, Oct. 1911, *J. L. Boorman* (NSW); *ibid.*, Oct. 1944, *W. Hartley* (CANB); Fladbury, 10 June 1953, *Jessup and Gray* 1918 (CANB); Copmanhurst, Oct. 1911, *H. M. Rupp* (NSW); Glen Innes, Dec. 1913, *J. L. Boorman* (BRI); *ibid.*, Mar. 1917, *J. Boorman* (NSW); Glen Elgin, Dec. 1913, *J. Boorman* (NSW); Guyra, 11 Jan. 1936, *L. Fraser* (NSW, SYD); *ibid.*, Mar. 1917, *J. Boorman* (NSW); Pleasant Hills, 1889, *Fischer* (MEL); Barraba, Sept. 1903, *R. D. Hay* 11 (NSW); Yarrowyck, 4 Mar. 1954, *Jessup and Gray* 2709 (CANB); Head of Gwydir R., 12 Apr. 1843, *Leichhardt* (NSW); Armidale, 20 Jan. 1941, *Davies* (SYD); *ibid.*, 18 Jan. 1929, *F. McDonald* (ADW); *ibid.*, *Perrott* (MEL); Walcha, 1884, *A. R. Crawford* 49 (MEL); Upper Macquarie R., Oct. 1882, *J. M. Curran* (MEL); Scone, 1883, *F. C. Carter* (MEL); *ibid.*, 31 Aug. 1907, *R. H. Cambage* 1691 (NSW); Blandford, 2 Oct. 1944, *H. M. Rupp* (NSW); Gungal, Sept. 1904, *J. L. Boorman* (NSW); Dubbo, 1882, *M. Curran* (MEL); Hastings R., *Dr. Beckler* (MEL); Mudgee, *Woolls* (MEL); Wingen, 30 Oct. 1909, *R. H. Cambage* (SYD); Lithgow, 2 Jan. 1936, *J.W.V., L.R.F. and J.M.W.* (SYD); Bowenfels, 2 Oct. 1904, *R. H. Cambage* 1150 (NSW); Bathurst, 22 Apr. 1889, *Deane* (NSW); Wallerawang, Dec. 1917, *J. L. Boorman* (AD); Hartley Vale, Nov. 1913, *A. A. Hamilton* (NSW); Jenolan Caves, Oct. 1899, *W. F. Blakely* (NSW); Lidsdale-Wallerawang, 2 Jan. 1941, *A.D.E.* (SYD). Kirkconnel State Forest, 23 Mar. 1947, *G. W. Althofer* (NSW); Forest Land, Cox's R., 9 Oct. 1822, *A. Cunningham* 71 (Type of *Helichrysum albicans* A. Cunn., MEL iso, K holo); *ibid.*, *S. G. Hannaford*

(NSW); Temora, Nov. 1916. *J. W Dwyer* 959 (NSW); Cavan, *I. Calvert* (MEL); Yass-Boorowa, 30 nov. 1953, *C. W. E. Moore* 281 (NSW); Yass, 30 Nov. 1953, *C. W. E. Moore* 2811 (CANB); Albury, Oct. 1916, *T. H. Patterson* 166 (NSW); Table Top, *H. Beattie* (MEL); Nail Can Hill, 17 Oct. 1949, *E. J. McBarron* 3810 (AD, SYD); *ibid.*, 22 Jan. 1949, *E. J. McBarron* 2995 bis (NSW), Braidwood, 30 Oct. 1908, *R. H. Cambage* 2082 (NSW, SYD); *ibid.*, 3100 ft., Dec. 1884, *W. Bäuerlen* 252 (MEL); *ibid.*, Feb. 1909, *J. L. Boorman* (NSW); Wagga Wagga, *Hammond* 1 (MEL); *ibid.*, 1888, *J. R. Garland* 18 (MEL); *ibid.*, 1884, *R. Thorn* (MEL); Tumbarumba, 8 Nov. 1919, *E. J. McBarron* 4001 (SYD); Lindsay station, 4 Nov. 1909, *R. H. Cambage* (SYD); Blue Mountains, *F. v. Mueller* (MEL); base of Mt. Kosciusko, Oct. 1887, *F. v. Mueller* (MEL).

VICTORIA. Beechworth, 1881, *Falck* 21 (MEL); Rutherglen-Chiltern, 19 Oct. 1950, *C. W. E. Moore* 1418 (CANB); Myrtleford, 1883, *Dr. Lucas* (MEL); Mt. Hotham, Jan. 1900, *J. H. Maiden* (NSW), *ibid.*, Jan. 1899, *G. Walter* (NSW); *ibid.*, 6100 ft., 13 Nov. 1952, *E. L. Robertson* 7290 (ADW); *ibid.*, 1890, *C. French* (MEL); Gippsland, 1882, *Howitt* 66 and 447 (MEL); Australian Alps, 3000 ft., 23 Oct. 1886, *Stirling* (?) 48 (MEL); Omeo, 1882, *Howitt* 639 (MEL); Upper Murray R., 1886, *C. French* (MEL); *ibid.*, 1888, *E. Rawes* 39 (MEL); Upper Yarra, Aug. 1891, *G. Walter* (G-DC, NSW); Red Jacket Creek, 1874, *Gargurevich* (MEL); Research, 12 Dec. 1947, *Canha* (GAUBA), Castlemaine, 1891, *P. Doreen* (NSW); Romsey, *Moffat* (MEL); Port Phillip, *F. v. Mueller* (MEL); Skipton, *Whan* 8 (MEL); Wimmera, *Dall.* (MEL); *ibid.*, *Curdie* (MEL); Healesville, 18 Oct. 1913, *K. Kelly* (G-DC); *ibid.*, *C. Walter* (G-DC, MEL); Little River, *Fullagar* (MEL); Station Peak, *F. v. Mueller* (K); You Yangs Mts., 5 Sept. 1906, *A. G. Campbell* (G-DC).

This variety exhibits considerable variation at the extremes of its distribution, both in its leaves and its involucral bracts. In the region south-west of Melbourne (the type locality of *H. incanum* var. *filifolium* F v M.), the leaves are filiform. In eastern Victoria around Mt. Hotham, they become thicker, perhaps due to the influence of subsp. *alpinum*, while in the westerly limits of its occurrence in New South Wales, they become flattened, and the plants smaller suggesting hybridization with *H. molle*. The variation in colour and shape of the involucral bracts is also great. Thus plants from central Victoria have lanceolate bracts, in the east and north-east of New South Wales and Queensland and they are narrowly ovate to oblong, while to the west they become more broadly ovate, again a tendency towards *H. molle*.

In Gippsland is found a form with pale yellow narrowly ovate intermediate involucral bracts and linear to narrowly oblanceolate leaves, this represents var. *flavidiceps* F v M. described from the Snowy River.

It seems probable that Mueller had no precise plant in mind when he described *H. incanum* var. *auriceps*, his description "involucral scales lanceolate, golden yellow" and "Australia Felix", one of the regions of distribution cited, would fit the central Victorian form of var. *albicans*, but Mueller also mentions it as occurring in the "Northern parts of South Australia" where the only plant in this group found is *H. molle*. It is possible that Mueller was not satisfied with his delimitation of the varieties of *H. albicans* as described in Rep. Babbage's Exped., for he does not appear to have used the varietal epithets in his later publications.

var. **buffaloensis** *P. G. Wilson* var. nov.—Figs. 3b, 7(4), 8(1).

Herba perennis suffrutescens. Bracteae involucri exteriores ovatae, rubrofuscae, interiores late ovatae vel deltoidea, flavae. Corolla 5 mm longa. Achaenia leviter verrucosa, obovoidea, 3 mm longa.

A tall erect perennial herb to 45 cm high, much branched, with the branches ascending from a woody base. Leaves linear closely lanate, scattered along the stem when flowering. Outer involucral bracts dark reddish brown, often streaked, the intermediate ones yellow with acute broadly ovate to deltoid laminae which are up to 10 mm long and 6 mm wide.

Distribution.—Apparently confined to Mt. Buffalo.

VICTORIA. Mt. Buffalo. 25 Dec. 1924, *MacGillivray* 1166 (NSW, ADW); 4,300 ft., 19 Jan. 1913, *R. H. Cambage* 3724 (NSW); Dec. 1902, *Boucher* (NSW); 4,000 ft., 9 Jan. 1950, *H. C. E. Stewart* (BRI); 3,000 ft., 10 Nov. 1955, *Gauba* (GAUBA, type).

It differs from *albicans* in being a taller plant, and in the colouring and shape of the involucral bracts, some collections from near Mt. Buffalo are, however, intermediate between var *buffaloensis* and var. *albicans* in this respect.

var. **graminifolium** *P. G. Wilson* var. nov. — Figs. 3e, 7(5). Herba perennis inferne lignosa ad 30 cm alta, dense compacta, ramosissima; rami maturi basibus rigidis foliorum delapsorum incrustati. Caulis annotinus dense foliatus, parce lanatus. Folia filiformia ad 12 cm longa, marginibus revolutis, supra glabra vena impressa, infra vena prominenti glabra aliter lanata. Pedunculus gracilis pauci bracteatus, apice versus lanatus, 8-15 cm longus. Involucrum hemisphericum, 2-2·5 cm latum. Bracteae involucro extreme sessiles, oblongae vel ellipticae, obtusae, scariosae, basi lanata, interiores stipitatae, stipite 3-3·5 mm longo, lamina elliptica ad 7·5 mm longa obtusa vel acuta basi lanata; bractea intimae stipite anguste scarioso-alato c. 4 mm longo, lamina oblonga c. 4 mm longa. Bracteae exteriores pallido-fuscae vel puniceae, interiores aureae vel flavae. Achaenia minute rugosa vel levia, turgida, leviter curvata c. 2 mm longa. Pappi setae 14-16, sub-plumosae, c. 4 mm longae.

Distribution. — Known only from the one district about 75 miles north-west of Sydney.

NEW SOUTH WALES. Clarence-Wolgan Road, 31 Dec. 1939, *W. F. Blakely, J. and W. J. Buckingham* 44378 (AD, NSW); *ibid.*, 26 Feb. 1939, *W. F. Blakely, J. and W. J. Buckingham* 8306 (AD isotype, NSW holotype); Wolgan Gap, 3,200 ft., 12 Apr. 1953, *L. Johnson* (NSW); Wolgan R., Nov. 1909, *H. Deane* (NSW).

This is a clearly distinguished variety noteworthy for its closely revolute leaves which are glabrous above and lanate beneath except for the glabrous midrib, and for the hard scale-like leaf bases on the old stems.

I am grateful to Sydney Herbarium (NSW) for sending me all their material of this interesting plant, and for the accompanying notes made on it by the late W. F. Blakely, whose manuscript epithet I have adopted.

var. **incanum** (*Hook.*) *P. G. Wilson* var. et comb. nov.

*Helichrysum incanum* Hook. Bot. Mag. t. 2881 (1829). Type, l.c. t. 2881.

*Helipterum incanum* (Hook.) DC. Prod. 6: 215 (1838); Hooker, Icones Pl. t. 318 (1841) p.p., as to tab. and Tasmanian plants cited; Hooker, Fl. Tasman. 1. 214 (1856); Rodway, Tasman. Fl. 85 (1903); Guilfoyle, Austral. Pl. 213 (1910?).

*Aphelexis incana* (Hook.) G. Don in Sweet, Hort. Brit. ed. 3. 379 (1839).

f. **incanum.**

*Helipterum incanum* var. *tricolor* DC. Prod. 6: 215 (1838). (Name illegitimate as the variety is based on Bot. Mag. t. 2881, the type figure of *H. incanum* Hook.); Hooker, Fl. Tasm. 1: 214 (1856); F. v. Mueller, Rep. Babbage's Exped. 14 (1859) p.p.

[*H. incanum* var. *purpureo-album* F v M. l.c., p.p., not as to lectotype.] — Figs. 5e, 7(7).

A perennial herb 10-40 cm high. Base branched and woody, covered with the persistent membranous bases of the old leaves. Branches erect, or slightly decumbent in old plants, lanuginose when young. Leaves more or less congested, narrowly linear to filiform with revolute margins, lanuginose, to 12 cm long. Involucre hemispherical, 2-5 cm. wide. Outer bracts oblong, sessile; intermediate ones stipitate, the lamina elliptic, usually narrowly so (occasionally narrowly ovate or obovate), apex obtuse, base ovate to narrowly cuneate, 10-15 mm long, 2-4 mm wide; stipe subulate to 6 mm long. The outer 5-6 rows of

involucral bracts with purple tips which become brown with age, the rest white. Achene four angled, ± smooth to coarsely verruculose, curved, 2·5-2·8 mm long.

Distribution.—Northern Tasmania.

TASMANIA. Circular Head, 3 Nov. 1841, *Milligan* 551 (MEL, HO); *ibid.*, 30 Jan. 1888, *Oakden* 115 (MEL); Circular Head Bluff, Sept. 1838, *Gunn* 108 (NSW); *ibid.*, Sept. 1838, *Gunn* 442 (NSW); Punt, Norfolk Plains, 8 Dec. 1842, *Gunn*, 108 (NSW); Middlesex Plains, 3000 ft., 19 Jan. 1842, *Gunn* 513 (MEL); *ibid.*, Feb. 1924, *L. H. Linden* (NSW); Scrubby Corner, Nov. 1848, *Archer* 71 (NSW); Cradle Mt.-Moina, 1 Feb. 1949, *N. T. Burbidge* 3528 (CANB, HO). Without definite locality: *R. Brown* (MEL); *Story* 32 (MEL); *C. Stuart* (G-DC, MEL); 1844, *Gunn* 55 (MEL); *Gunn* 108 (MEL, K), 100, 124 (origin of Icones figure) (K), 1863 s.n. (G-DC).

This form is restricted to northern Tasmania. It is similar to the south-east Australian f. *purpureo-album* which also has purple tipped outer involucral bracts. In the latter plant, however, the bracts are smaller, normally ovate to oblong, usually acutely tipped, while the disc is of a deeper yellow colour.

W. J. Hooker in his description of *H. incanum* (Bot. Mag. t. 2881) states that the inner involucral bracts are pale yellow or cream-coloured, the intermediate ones tipped with red, and the outer white, while De Candolle in his Prodromus, under var. *tricolor* based on the same figures in the Bot. Mag., describes the inner ones as white, intermediate yellow, and outer purple, which statement is repeated by Mueller in Rep. Babbage's Exped. 14 (1859). I have not seen any specimens of Tasmanian plants with yellow bracts, although various colour combinations sometimes occur on the mainland. The seed from which the plant illustrated in the Botanical Magazine was grown, is said to have come from Tasmania, but no details are given, and I have not been able to find any corresponding specimen in the Kew Herbarium.

f. **grampianum** *P. G. Wilson* form. nov.—Figs. 5A, 7(8).

Bracteae involucri interiores lanceolatae, acutae vel acuminatae 12-14 mm longae, 4-5 mm latae. Folia filiformia, lanata.

Distribution.—The Grampian Region of Victoria.

VICTORIA. Mt. Emu, *F. v. Mueller* (MEL); Skipton Plains, 1860, *W. J. Whan* 39 (MEL holotype, NSW iso); Grampians, 1885, *F. v. Mueller* (MEL); *ibid.*, *Wilhelmi* (MEL); Western Plain of Victoria, 1857, *Wilhelmi* (MEL); "Loamy Plains towards the Grampians", *anon.* (MEL); Wickliffe, Nov. 1908, *J.P.M.* (MEL); "Interior of New Holland", 1814, *Mitchell* (MEL).

This variety has a very limited distribution as is indicated above. It appears from the collections available that there is no continuity of distribution with the south-eastern form of f. *purpureo-album*, although intermediates occur between f. *grampianum* and the western Victorian form of f. *purpureo-album*.

It closely resembles the Tasmanian f. *incanum* but has characteristic acutely lanceolate reddish-brown involucral bracts.

f. **purpureo-album** (F v M.) *P. G. Wilson* form. et comb. nov.

*H. incanum* (Hook.) DC. var. *purpureo-album* F v M. Rep. Babbage's Exped. 14 (1859) p.p. Lectotype "Maneroo Plains" [Monaro], 1855, F. v. Mueller (MEL).

*H. bicolorum* A. Cunn. ex DC. Prod. 6: 215 (1838). Type "Hills of the Lachlan River" 33°4'2''S., 146°47'30''E., A. Cunningham, 31 July 1817 (holo G-DC photo, iso K, MEL, BRI).

[*H. incanum* (Hook.) DC. var. *tricolor* (non DC. sensu stricto) — F. v. M. Rep. Babbage's Exped. 14 (1859) p.p.]

[*H. incanum* (non (Hook.) DC. sensu stricto) — Guilfoyle, Austral. Pl. 213 (1910?) p.p.—Figs. 3A, 7(6), 8(3).

Leaves filiform to linear or narrowly oblanceolate. Involucre 2-2·8 cm wide. Outer bracts pale brown to purple, intermediate bracts oblong to ovate (or rarely elliptic) obtuse to acute, 5-8 (10) mm long. Disc yellow.

Distribution. — South-east New South Wales, south-west and south-east Victoria.

New South Wales. Gulgong, *Barnard* 89 (MEL); Dubbo, 29 Sept. 1911, *J. B. Cleland* (AD); Mudgee, 1870, Taylor (MEL); Mudgee South, 16 Oct. 1953, *M. Tindale* (NSW); Wellington, Oct. 1883, *Betche* (NSW); Hill End, 3 Jan. 1925, *MacGillivray* 1172 (NSW, ADW); *ibid.*, Apr. 1885, *J. Lauterer* 28 (MEL); Bathurst, Apr. 1817, *A. Cunningham* (BRI); Trunkey, 18 Nov. 1918, *J. Boorman* (NSW); Trunkey Cr., 22 Oct. 1951, *K. Muir* (AD); Abercrombie district, Jan. 1936, *J. Wiburd* (NSW); Abercrombie Caves, Nov. 1918, *J. Boorman* (NSW); Lachlan R., July 1817, *A. Cunningham* 302 (Type of *H. bicolorum* DC.?) (BRI); Laggan-Tuena, 15 Oct. 1953, *C. W. E. Moore* 2682 (NSW, CANB); Berrima, Apr. 1889, *H. Deane* (NSW); Goulburn, Sept. 1916, *J. W. Dwyer* 848 (NSW); Bundanoon, 15 Apr. 1947, *M. Tindale* (NSW); Oldbury [near Berrima], *L. Atkinson* 16 (MEL); Midway rivulet, *L. Atkinson* 17 (MEL); Wingello, *anon.* (NSW); *ibid.*, Feb. 1901, and Dec. 1913, *J. L. Boorman* (C-DC); Tallong, 28 Oct. 1933, *E. Cheel* (NSW); *ibid.*, 1 Jan. 1935, *O.D.E.* (SYD); Yass district, Bango Quarry, 3 June 1949, *R. A. Oxenford* (NSW); Yass-Gunning, 12 Oct. 1953, *C. W. E. Moore* 2629 (NSW, CANB); Tarago, 25 Sept. 1928, *A. Morris* (ADW); Barbers Creek, Oct. 1899, *H. J. Rumsey* (SYD); *ibid.*, *H. J. Rumsey* 98 (NSW); *ibid.*, Oct. 1898, *J. H. Maiden* (BRI); Braidwood, 30 Oct. 1908, *R. H. Cambage* 2082 p.p. (SYD); *ibid.*, 3200 ft., Jan. 1885, *W. Bäuerlen* 362 and 390 (MEL); Marulan, 25 Oct. 1948, *E. J. McBarron* 2436 bis (NSW, SYD); Cavan, *I. S. Calvert* (MEL); Castlereagh R., *Woolls* (MEL); Cobar, 1887, *H. Andrae* 342 (MEL); Port Jackson, *anon.* (MEL); New Adaminaby-Cooma, 21 Jan. 1958, *J. Thompson* 48 (NSW); Cooma, 2 Nov. 1908, *R. H. Cambage* 2101 (NSW, SYD); Cooma district, Dec. 1896, *anon.* (AD); Nimmitabel-Cooma, Dec. 1896, *J. H. Maiden* (NSW); Nimmitabel, Dec. 1916, *J. Boorman* (NSW, SYD); Kybean, 5 Nov. 1908, *R. H. Cambage* 2123 (NSW, SYD); Maneroo Plains [Monaro], 1855, *F. v. Mueller* (MEL lectotype).

A.C.T. Nr. Mt. Majura, 24 Sept. 1950, *C. W. E. Moore* 1415 (CANB); Canberra, 1 Nov. 1949, *Gauba* (GAUBA); Ainslie-Duntroon, Oct. 1947, *H. R. Browne* (CANB).

Victoria. Hamilton, Oct. 1900, *H. B. Williamson* (BRI); Macarthur, Nov. 1896, *H. B. Williamson* (NSW); *ibid.*, Nov. 1894, *H. B. Williamson* (MEL).



Fig. 5.—A, Distribution of *Helipterum albicans* f. *grampianum*; B, subsp. *alpinum*; C, f. *incanum*.
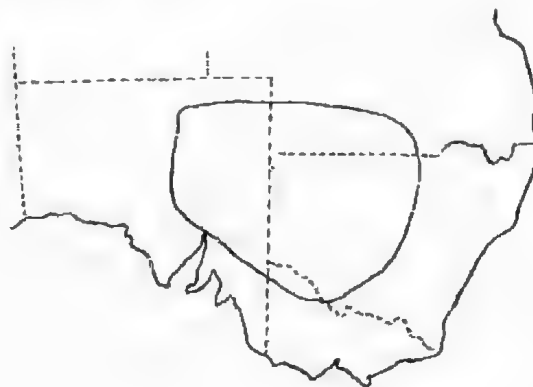
Fig. 6.—Distribution of *Helipterum molle*.

In the northern limits of its distribution this form has smaller capitula and involucral bracts, and agrees closely, except for colour, with the eastern New South Wales form of var. *albicans*. In the south, the capitula and involucral bracts are larger although they do not reach the size of those found in f. *incanum*. the south-west Victorian plants have flat linear leaves and white to pale-brown outer involucral bracts, and grade to the east into f. *grampianum*.

In south-east New South Wales from Collector south to Cooma occurs a form with the outer involucral bracts brown to reddish brown, the intermediate ones white, and the inner yellow fading to white with age. This may be a hybrid between f. *albicans* and f. *purpureo-album*. Collections of this form are: Collector, *R. Hill* 1003 (AD); Queanbeyan, *M. Mueller and S.W.* 2117 (COOMA); Cooma, *M. Mueller* 780 and 780a (COOMA); Goulburn—Collector, *Hj. Eichler* 13312 (AD).

F. v. Mueller gives the following description and distribution of var. *purpureo-album*: "inner involucre scales white, outer ones purple or brown. Tasmania, Maneroo, Snowy River, Grampians, Glenelg River, Bathurst, etc." He cites no specimens. I am here excluding from *purpureo-album* the Tasmanian and Grampian plants, and have chosen as a lectotype as specimen collected by Mueller at "Maneroo" previous to the publication of his variety.

subsp. **alpinum** (F v M.) *P. G. Wilson* subsp. et comb. nov.

*Helipterum incanum* (Hook.) DC. var. *alpinum* F v M. Rep. Babbage's Exped. 14 (1859). Type, "Summit of the Australian Alps" F. v. Mueller (iso K, NSW, holo MEL).—Figs. 5B, 7(9), 8(2).

A decumbent perennial herb 10-24 cm high; base woody, branching, covered with persistent membranous brown leaf bases. Young stems densely lanuginose. Leaves thick, congested, densely lanuginose, obovate to oblanceolate, with the apex obtuse to rounded, 2·5-6 cm long, 0·6-1 cm wide. Peduncle terminal lanuginose, 4-12 cm long. Involucre hemispherical, 2·6-4 cm wide, with numerous bracts. Outer bracts sessile, ovate to lanceolate, intermediate ones with the lamina narrowly ovate, obtuse to acute, 10-12·5 mm long, 4 mm wide. The outer bracts pale reddish brown to pale brown, the intermediate white and the innermost sometimes with a purple spot at the lamina base. Disc yellow. Corolla 4·5-5 mm long, pappus setae subplumose 4·5-5·3 mm long. Achene smooth, obscurely 4-angled, obovoid, slightly curved.

Distribution.—The Australian Alps.

NEW SOUTH WALES. Mt. Kosciusko, Feb. 1946, *P.U.M.* (SYD); Jan. 1953, *A. T. Hotchkiss* (SYD); Feb. 1928, *J. McLuckie* 116 (SYD); Feb. 1927, *P.B.* (SYD); 7000 ft., 12 Mar, 1957, *C. L. Wilson* 440 (NSW); Feb. 1954, *G. W. Althofer* (NSW); Dec. 1892, *J. Kretschmar* (NSW); Dec. 1912, *H. M. R. Rupp* (NSW); Jan. 1901, *C. H. Grove* (G-DC, MEL); 7200 ft., *M.S.* 23 (MEL); Jan. 1885, *Van Lenderfeld* (MEL); Jan. 1889, *J. H. Maiden und W. Forsyth* (MEL, AD); Jan. 1925, *J. McLuckie and A. H. K. Petrie* (CANB); Nov. 1928, *J. McLuckie* 116 (CANB); 7000 ft., 30 Jan. 1953, *M. Mueller* 781 and 781a (COOMA); 6500 ft., 22 Jan. 1952, *Gauba* (GAUBA); Feb. 1901, *R. Helms* (AD); 7100 ft., *anon.* (AD), 10 Dec. 1910, *J. B. Cleland* (AD); Mt. Kosciusko, White's Creek, 6000 ft., *Johnson and Constable* (NSW); Mt. Kosciusko Range, Jan. 1880, *Findlay* (MEL); Mt. Kosciusko, above Lake Albina, 6800 ft., 20 Jan. 1931, *Johnson and Constable* (NSW); Betts Camp-Mt. Kosciusko, 16 Feb. 1914, *J. H. Maiden* (NSW); Snowy Mts., Blue Lake, c. 6300 ft., 5 Feb. 1957, *Eichler* 13670 (AD); Snowy Mts., 7000 ft., Feb. 1890, *W. Bäuerlen* 65 (MEL). Mt. Townsend, 7250 ft., 5 Mar. 1889, *R. Helms* (NSW); Munyang Mts., 6-7000 ft., Jan. 1874, *F. v. Mueller* (MEL).

VICTORIA. Mt. Hotham, Jan. 1900, *J. H. Maiden* (NSW), ibid., Jan. 1899, *C. Walter* (NSW, MEL, CANB); ibid., Dec. 1914, *A. J. Tadgell* 75 (MEL); ibid., 1890, *C. French* (MEL), Bogong High Plains, nr. Mt. Nelse, c. 6300 ft., 13 Feb. 1958, *Eichler* 14845 (AD); "Summit of the Australian Alps", *F. v. Mueller* (K isotype, NSW iso?, MEL holo).

subsp. alpinum X f. purpureo-album?

NEW SOUTH WALES. Happy Jack's Plain, 4850 ft., 18 Jan. 1958, *J. W. Vickery* (NSW).

A.C.T. Tidbinbilla, 5115 ft., 7 Nov. 1911, *R. H. Cambage* (CANB, SYD); Mt Franklin, 11 Feb. 1953, *C. W. E. Moore* 2356 (CANB, NSW); ibid., 7 Feb. 1947, *N. T. Burbidge* 1711 (CANB); Brindabella Range, c. 4000 ft., 24 Feb. 1959, *E. Gauba* s.n. (AD).

VICTORIA. Dargo High Plains, 1883, *Howitt* (MEL); Delegete, 1882, *Howitt* 575 (MEL).

This subspecies is conspicuous because of its broad thick leaves and relatively short peduncles (but when cultivated at lower altitudes the peduncle

becomes considerably longer). Towards the north, as far as Mt. Franklin, the leaves become narrower and the capitula smaller, grading into the northern form of f. *purpureo-album*. Similarly in south-eastern Victoria, in districts adjacent to those where *alpinum* occurs, are found plants more or less intermediate between *alpinum* and the southern form of f. *purpureo-album*.
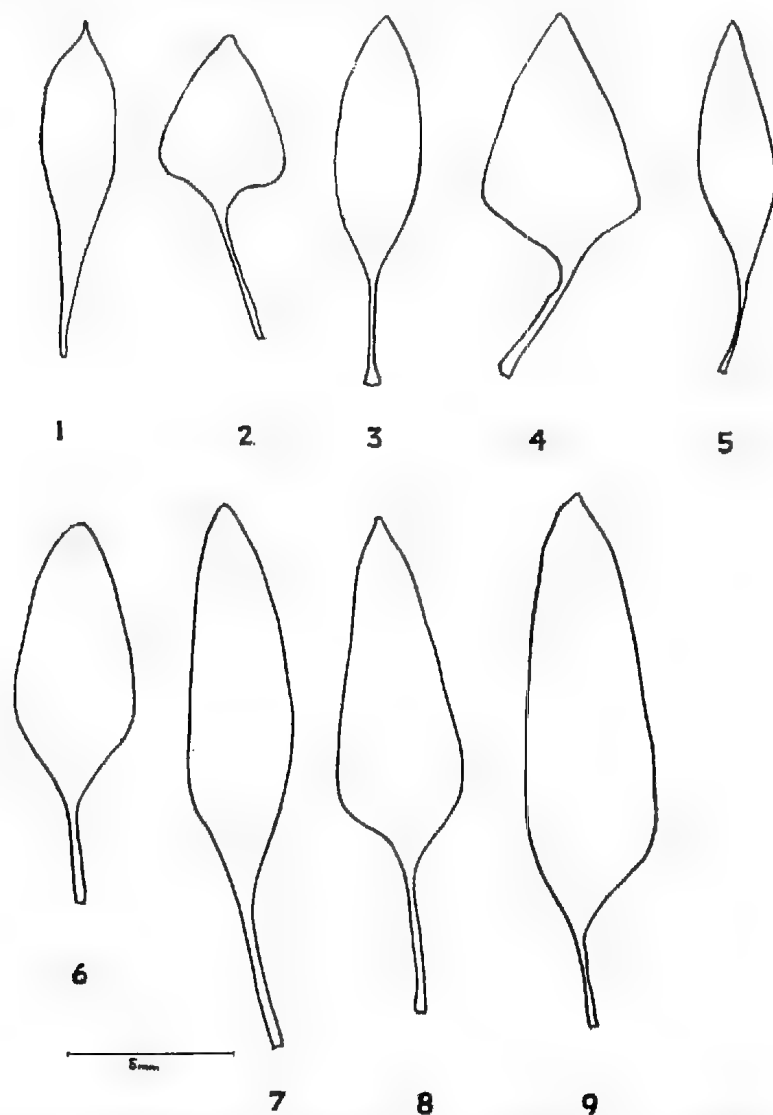


Fig. 7,—Intermediate involucral bracts (outline only): 1, *Helipterum saxatile*; 2, *H. molle*; 3, *H. albicans* var. *albicans*; 4, var. *buffaloensis*; 5, var *graminiforlium*; 6, var. *incanum* f. *purpureo-album*; 7, f. *incanum*; 8, f. *grampianum*; 9, subsp. *alpinum*.

**H. molle** (*A. Cunn.* ex. DC.) *P. G. Wilson* comb. nov.

*Helichrysum molle* A. Cunn. ex DC. Prod. 6: 194 (1838). Type, Molle's Plains, Lachlan River, New South Wales, July 1817, A. Cunningham (holo G-DC photo).

*Waltzia brachyrrhyncha* F v M. Linnaea, 25: 407 (April 1853). Type, Cudnaka [Kanyaka], Flinders Range, S. Australia, F. v. Mueller (holo MEL).

*Helipterum brachyrrhynchum* (F v M.) Sond. l.c. 517 (June 1853).

*H. incanum* (Hook.) DC. var. *brachylepis* F v M. Rep. Babbage's Exped. S. Austral. 14 (1859). "Flinders Ranges, etc." Presumably based on *W. brachyrrhyncha* F v M. which was cited in the general synonymy under *H. incanum* by Mueller in the same paper.

[*H. albicans* (non (A. Cunn.) DC.) — J. M. Black. Fl. S. Austral. 624 (1929) p.p., and 2nd ed. 901 (1957) p.p.] — Figs. 6, 7(2), 8(4).

An erect annual herb, 6-30 cm high, branching at the base. Leaves scattered, sessile, broadly linear to oblanceolate, lanate, to 7 cm long and 0·7 cm wide, apex obtuse to acuminate, apiculate. Involucre hemispherical, the outer bracts broadly ovate, colourless to light yellowish brown or tinged with light red when young, intermediate ones stipitate, the lamina golden yellow 3-10 mm long, broadly ovate to suborbicular, apex rounded to obtuse, base rounded to truncate. Achenes densely and prominently papillose, tetrangular, c. 3 mm long.

Distribution.—Southern central South Australia, south-west Queensland, west and central New South Wales and north-west Victoria.

QUEENSLAND. Thargomindah, 1883, *Spencer* (MEL.); Cunnamulla, 22 July 1941, *R. Roe* R357 (CANB); *ibid.*, 6 Sept. 1947, *G. H. Allen* A346 (CANB). Cairwarro, Sept. 1885, *T. Cotter* (MEL).

NEW SOUTH WALES. Fort Grey, 20 Aug. 1950, *N. A. Burges and N. C. Beadle* (SYD, NSW); Evelyn Cr., 1887, *A. King* (MEL). Warrego R., 1882, *E. C. Close* 51 (MEL); Warrego. *L. Henry* 57 p.p. (MEL); Barrier Range, Sept. 1921, *M. J. Collins* (SYD); *ibid.*, 1889, *J. F. Irvine* (MEL); *ibid.*, 1893, *H. Deane*; Silverton, Sept. 1884, *anon.* (MEL); Byrock, Sept. 1885, *E. Betche* (NSW); *ibid.*, Sept. 1885, *anon.* 7 (MEL), Broken Hill, 4 Oct. 1920, *A. Morris* 437 (NSW, ADW); *ibid.*, Aug. 1926, *E. Cheel* (NSW); Wilcannia, 1886, *B. Kennedy* 27 (MEL); *ibid.*, 1885, *B. Kennedy* (MEL); Warrigal, 11 Oct., *anon.* 451 (NSW); Mt. Brown, Sept. 1898, *anon.* (NSW); Mt. Manara, 20 Nov. 1956, *T. and J. Whaite* 2105 (AD); Gulargambone, 27 Sept. 1952, *H. S. McKee* 208 (SYD); Darling R., 14 Oct. 1860, *F. v. Mueller* (MEL.); Bogan R.-Darling R., 1877, *L. Morton* (MEL); Darling R.-Lachlan R., Aug. 1855, *J. Brickner* (MEL); Hillston, 1889, *Evans* (MEL); Warroo, Nov. 1939, *K. Morris* (NSW); Booligal, Sept. 1887, *A. Bell* (MEL); Lower Edwards R., *Wein* (MEL); Castlereagh R., 1885, *Brumby* (MEL); Wentworth, Oct. 1887, *J. Minchin* (MEL); Darlington Point-Hay, 3 Sept. 1950, *C. W. E. Moore* 1349 (CANB); Moruadah, 5 Sept. 1950, *C. W. E. Moore* 1360 (CANB); Trangie-Narromine, 8 Oct. 1947, *C. W. E. Moore* M375 (CANB); Deniliquin, 21 Oct. 1945, *C. W. E. Moore* (CANB); *ibid.*, Sept. 1945, *W. M. Willoughby* F7 (CANB); Jerilderie, 21 Oct. 1950, *C. W. E. Moore* 1430 (CANB); Wanganella, Oct. 1903, *E. Officer* (AD); *ibid.*, *L. Kuentz* (MEL).

VICTORIA. Murray R., *anon.* (MEL); Swan Hill, *Gummow* (MEL).

SOUTH AUSTRALIA. Evelyn Downs, Oodnadatta, Oct. 1950, *E. H. Ising* 3973 (AD, ADW). Wangiana, 7 Aug. 1931, *J. B. Cleland* (AD); *ibid.*, 18 Aug. 1933 and 21 Aug. 1931, and 19 Aug. 1932, *E. H. Ising* (AD); Mt. Lyndhurst, July 1899, *Max Koch* (AD); *ibid.*, Aug. 1899, *Max Koch* 465 (AD, NSW); Blinman, 10 Oct. 1894, *W. E. Rumball* (AD); Quorn, Sept. 1927, *anon.* (AD); Leigh's Creek (Copley), 15 Oct. 1917, *Herb. J. M. Black* (AD). Kingoonya, 23 Sept. 1920, *E. H. Ising* 1854 (NSW, AD); Cockburn-Mingary, 15 Aug. 1921, *A. Morris* (ADW); *ibid.*, 14 Aug. 1921, *A. Morris* 652 (BRI, AD); Pt. Pirie, *anon.* (AD); Gladstone, *anon.* (AD); Gawler Ranges, Aug. and Sept. 1912, *White* (AD); Lake Gairdner, 18 Oct. 1958, *P. Wilson* 589 (AD); Cudnaka [Kanyaka], *F. Mueller* (MEL); Spencer Gulf-Mt. Elbe, *E. Giles* (MEL); Central S. Australia, *anon.* (AD).

AUSTRALIA. "Nov. Holl. austr. inter", *F. v. Mueller* (MEL).

This species exhibits considerable variation in the shape of the involucral bracts and in the papillosity of the achenes. In specimens from the more northern districts the bracts are deltoid to sub-orbicular with rounded apices, while in the southern districts they become ovate and obtuse. Towards the easterly limits of its distribution forms intermediate between *H. molle* and *H.*

*albicans* var. *albicans* are found, but the typical South Australian plant and the typical New South Wales form of *II. albicans* are so distinct that specific delimitation seems warranted.

It may be distinguished by its flaccid oblong to oblanceolate leaves, its normally golden-yellow involucral bracts which are normally deltoid in shape, the normally dense papillosity of its achenes and its annual, not perennial, nature.

I should like to thank Mr. R. Schodde for his help, while visiting the Melbourne Herbarium he made notes and drawings for me of the type of *Helipterum incanum* var. *brachylepis*.
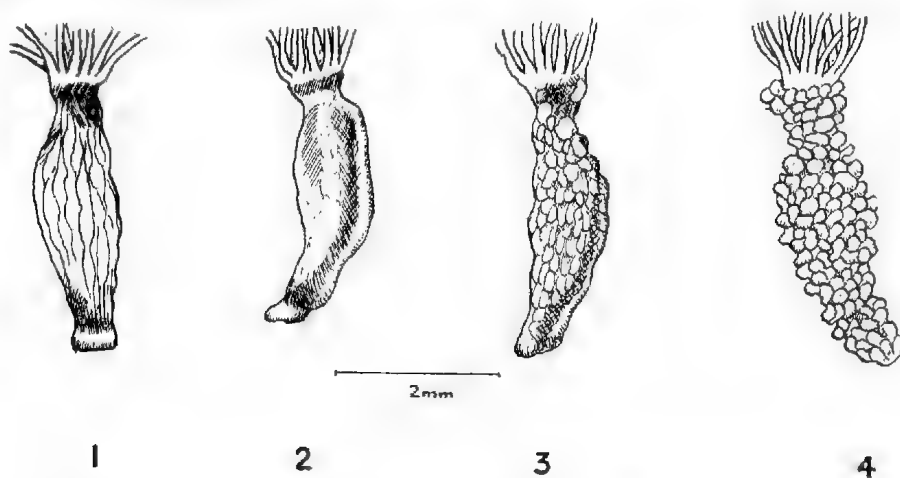


Fig. 8.—Achenes: 1, *Helipterum albicans* var. *buffaloensis*; 2, subsp. *alpinum*; 3, f. *purpureo-album*; 4, *H. molle*.

## ACKNOWLEDGMENTS

# ON SOME STRUCTURAL DEVELOPMENT IN THE CENTRAL PART OF THE GREAT AUSTRALIAN ARTESIAN BASIN

*BY H. WOPFNER, PH.D*

## Summary

Newly discovered structures outcropping in the central part of the Great Australian Artesian Basin are described. They are situated in the extreme north-east corner of South Australia and the adjoining area in Queensland. The structures, which are developed in sediments of lower Upper Cretaceous age, consist of a half-dome in the south (Cordillo Uplift) from which two lines of anticlines develop, one to the north and a second one to the north-east. Each line comprises several huge anticlines with "closure" between them. The Nappamilkie anticline and the Betoota dome are the most prominent structures of the western development (trend approximately north), whilst Mt. Howie anticline, Curalle dome and Morney anticline form the eastern line (trend approximately N. 30°E.) The individual closure of the structures is of the order of 400 feet to at least 600 feet. The dips on the limbs of the anticlines range from 2 degrees to 20 degrees. The two lines of anticlinal development are divided by the north-plunging Haddon syncline and its northern continuation, the Farrars syncline. The folding movements were initiated in Upper Cretaceous time, and probably reached a climax during the early Tertiary. Transcurrent movements in the deep-seated "basement"-rocks are thought to be responsible for the folding.

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[Read 9 April 1959]

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## INTRODUCTION

More than 30 years ago, R. Lockhart Jack, visiting Cordillo Downs Station, observed indications of a large, dome-like structure occupying the extreme north-east corner of South Australia. In 1925 and 1930 he published several cross-sections through the southern and south-western part of the area. These cross-sections were based mainly on water-bore logs and the correlations were based on similarities of water analyses within the different water-bearing horizons.

Since then, Jack's observations were almost forgotten and were given only passing reference in later geological literature.

In the course of petroleum exploration on behalf of SANTOS Ltd., R. C. Sprigg, Managing Director of Geosurveys of Australia Limited, used this information to select the Cordillo area as a possible prospect. Early in 1957, the author was sent to Cordillo Downs to obtain first-hand information, and a short ground and air reconnaissance was carried out. Parts of south-western Queensland were also included in this reconnaissance. Jack's observations were found to be basically correct in so far as the southern development was concerned, but the dome-like Cordillo structure further north proved to sub-divide into two major lines of anticlines. Moreover, three additional large elongated domes, the Betoota dome, the Curalle dome and the Morney anticline, were discovered across the Queensland border.

Several domes and anticlines were revealed in subsequent aerial surveys. The most important of them are: the Innamincka dome, situated between Innamincka and Lake Pure (Sprigg, 1958); the Orientos structure, a dome-like

* Geosurveys of Australia Limited.

upwarp north of Orientos station; several complex anticlines which form the McGregor Ranges between Wilson Creek and Cooper Creek; the Mooraberry anticline north of the Betoota dome; the Turret Hill anticline north of the Morney anticline.

Later in 1957, the Cordillo area was mapped in detail, and reconnaissance-investigations were carried out on the Betoota and Curalle domes.

The present paper is concerned only with the geological structures about Haddon Corner. The area dealt with is shown in Figs. 1 and 2.
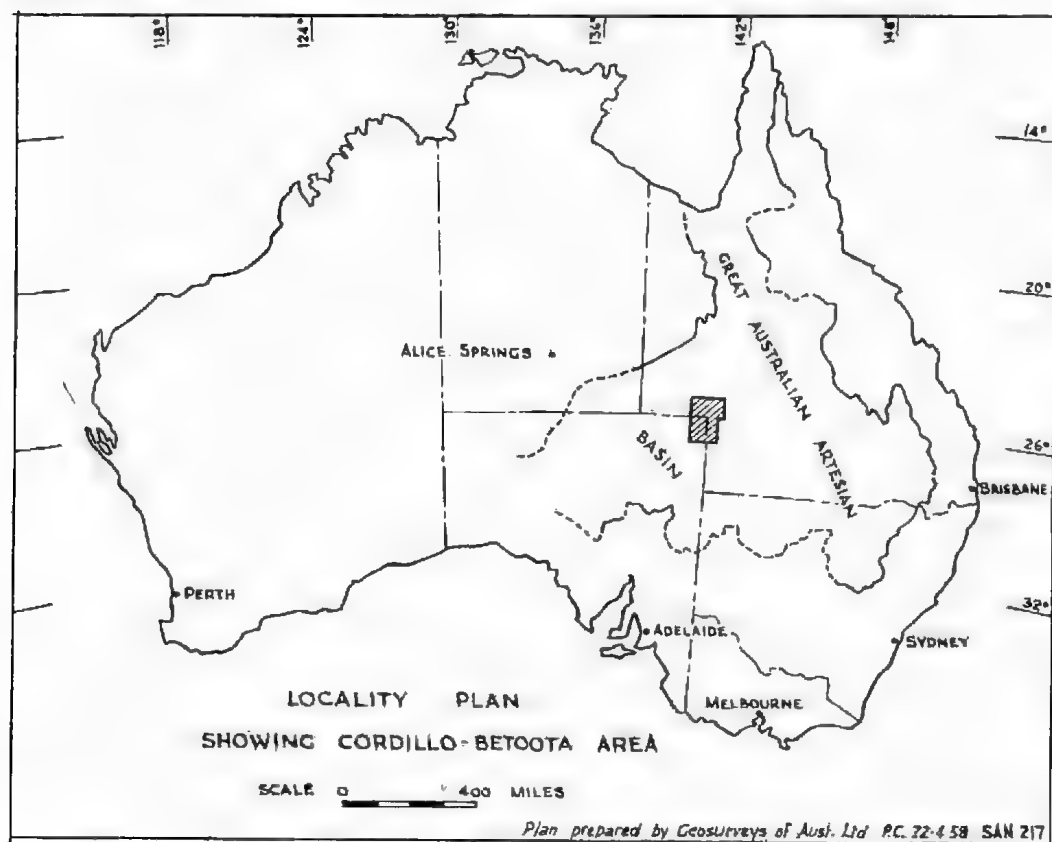


Fig. 1.—Locality plan, showing boundary of Great Australian Artesian Basin and area described.

## PHYSIOGRAPHY AND GENERAL GEOLOGICAL FEATURES

The structures described in this article lie in the central part of the Great Australian Artesian Basin, in the extreme north-east of South Australia and in the bordering region of south-west Queensland. The area is bounded by latitudes 25°15′S. and 27°00′S., and by longitudes 140°15′E. and 141°15′E. (see Figs. 1 and 2).

The country is undulating, and is dominated by table-topped hills and large flats covered by gibbers formed in the breakdown of siliceous duricrust. In the northern part, the flanks of the anticlines form NNE-SSW trending cuestas, with their slopes also covered with gibbers. The structures form the watershed between the Diamantina River and the Cooper Creek. The climate is arid with

CONTOUR PLAN SHOWING

STRUCTURES OF THE CORDILLO-BETOOTA AREA

Contours based on duricrust phantom
horizon.    Contour interval 100 feet

SCALE    0          10          20          30    MILES

H. Wopfner Ph.D.  Plan prepared by Geosurveys Aust Ltd.  RC. 22·4·58  SAN. 216
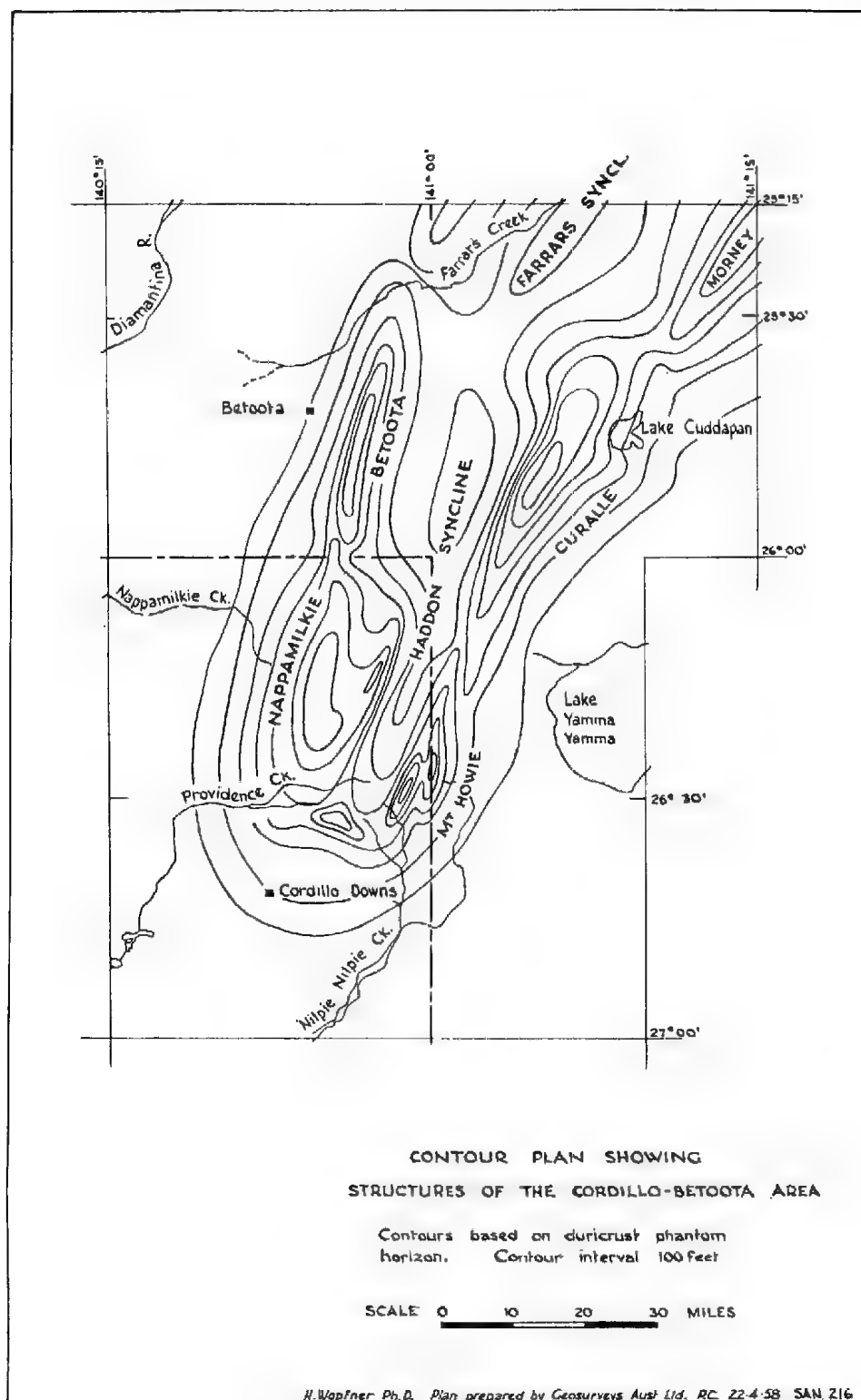
Fig. 2

an average annual rainfall of about 6 inches. Sandy deserts occupy the low-lying great plains.

Most of the stratigraphic members exposed at the surface belong to the Winton formation of lower Upper Cretaceous age, most probably Cenomanian. Only the uppermost part of the Winton can be observed in outcrop, the maximum exposure being about 350 to 700 feet. The sediments are mainly sandstones, siltstones, mudstones and shales, thinly bedded in the lower section, but occurring in thick banks in the upper development. Plant fossils (*Brachiphyllum, Elatocladus*, etc.), carbonaceous shales and thin coal seams are common. In the lowest exposed zones, layers and lenses of calcareous sandstone, interbedded with partly concretionary, and sandy, or marly limestones occur. This calcareous horizon is henceforth referred to as the "Betoota limestone horizon". At two outcrops of Betoota limestone, ripple marks with orthorhombic symmetrical features (wave ripples) were observed.

Within sandstones and siltstones, current bedding is very common. Para-diagenetic slumping is common throughout the whole sequence.

In several places, particularly on the limbs of the anticlines, the Cretaceous is overlain by conglomerates, grits and torrential bedded sandstones. Apart from silicified wood no fossils have been found, but generally these sediments are regarded as lower Tertiary. The contact between the Cretaceous and the Tertiary shows a slight erosional disconformity including cut-and-fill effect. Only along the south-east limb of Morney anticline has an angular unconformity of 2 degrees been observed (see Fig. 4).

The top layers of the sediments (Cretaceous and/or Tertiary) are strongly kaolinised and bleached. Below the bleached horizon a mottled zone is developed. The thickness of this altered horizon (bleached and mottled) varies between 100 and 250 feet. The bleached horizon is capped by a hard and highly silicified crust, commonly known as duricrust. The duricrust averages a thickness of 15 to 30 feet. The time of formation of the duricrust is uncertain, but it has to be placed after the Tertiary sediments were deposited.

In synclines and generally in structural depressions, the duricrust is overlain by red, nodular laterite and lateritised sands. Their maximum observed thickness is 120 feet in the Haddon syncline. At several localities a thin conglomeratic bed, built up by well-rounded pebbles of duricrust (diameter 1 to 3 inches), is present between the duricrust and the laterite.

In low situations the laterites are covered by sand-dunes and recent river silts.

## THE FOLD STRUCTURES

Approaching Cordillo Downs from the south, one notices a remarkable change in landscape. The sand-dunes which predominate the flat country give way sharply to large stony plains (gibber-plains) rising gently to the north. These gradually lead on to a strongly dissected region of table-topped hills. Comparable features will be observed when the area is approached either from the west across Rainbow Plain or from the east. This sudden change has its reason in the geological structure of the area. The gently rising, gibber-covered slopes represent *dip slopes* of the southern-most part of a large area of upwarping. Quaquaversal dips of 3 degrees to 4 degrees to the west, south and south-east mark this southern part of the structure. The beds rise from 220 ft. M.S.L. at Cordillo to about 650 ft. M.S.L. north of Needle Hill, where a steep, ENE-WSW trending escarpment forms the southern margin of the valley of Providence Creek (compare Fig. 3, cross-section 1). The escarpment gradually reduces its height towards the west and finally disappears under the alluvial

deposits of Rainbow Plain. To the east it swings into a NNE-direction, and there forms the eastern edge of the valley of Haddon Creek and its tributaries.

At the latitude of Providence Creek, the structure, which so far has the simple form of a half-dome, divides into two distinct anticlines. The western structure is henceforth referred to as *Nappamilkie uplift* and has a general northern trend, whilst the eastern structure, now referred to as the *Mt. Howle anticline*, trends 30 to 35 degrees east. The intervening syncline is the *Haddon syncline* (see Figs. 2 and 3, section 2).

There are indications to suggest a minor fault line along Providence Creek. The southern part would appear to be the downthrown side, and the amount of throw increases from east to west. However, the amount of faulting would not exceed about 30 feet in total.

The Nappamilkie uplift forms a broad, flat-topped, upwarped area, its main development being situated between the meridians 140°42′E. and 140°44′E. It comprises two anticlinal culminations, a western one with an axial trend of N5°E. and another in the east, trending N20°E. Both culminations are connected by an extremely shallow syncline, which deepens gradually towards its northern end (see Fig. 2). Limb dips average 2 to 8 degrees to the west and 12 to 20 degrees on the eastern limb. The two anticlinal culminations have an obvious plunge to the north.

The western limb of the structure forms gibber-covered dip slopes which are drained by several systems of consequent stream channels (Doonoonara, Koonabera and Nappamilkie Creeks). In the southern zone, between Providence and Koonabera Creeks, the beds show a constant dip of 2° to 2½°W. North of Koonabera Creek, particularly within the drainage area of Nappamilkie Creek, the dips on the flank of the structure attain 8°W., but flatten to about 1½°W. further west. The strike is about N.5°E., except in the extreme northern portion of the limb where it is N.20° to 25°E., and dips are at 4°W. The apex of this western anticline is roughly marked by the watershed between Nappamilkie Creek, Koonabera Creek and Doonoonara Creek, flowing westwards, and the eastwards draining creeks Jiblic, Kuchumba and Haddon. The culmination at about 700 ft. M.S.L. is marked by the star-like divergence of the Nappamilkie- Kuchumba- and Haddon Creeks. From this area of culmination, the long axis, trending N.5°E., plunges at about 2° to the north, and ½° to the south. Again, in the extreme northern part of the anticline, the plunge increases to 4°, forming a shallow closure. In this extreme northern portion the erosion removed most of the eastern limb of the anticline, cutting well back beyond the apex into the western flank. In this area, the beds of the eastern limb show a general direction of N.15°W., and dip 4°E. (see Fig. 2).

South of the headwaters of Kuchumba Creek the eastern limb has a dip of 2°, but soon flattens out to near horizontal position. To the east, a slight reversal of dip is indicated (½° to 1°W.). The central parts of these flat-lying beds form the large Lamamour Plateau (see Fig. 3, Section 2).

On the eastern margin of the Lamamour Plateau (north of the ruins of Haddon homestead) strong shearing planes have been observed. The main zone of shearing trends about N.35°E. Several irregular fractured zones cross the main one at angles between 40 and 50 degrees, and very much resemble the pattern of feather joints. All shear zones are vertical or near vertical and uneven. Well developed slickensides are prominent along all of them and some autoclastic breccias are present. These and other indications suggest minor faulting along the direction N.35°E. with a downthrow of the eastern part of about 20 feet and causing dips of up to 12°W. (compare Fig. 3, Section 2).

East of this shear zone the beds rise with an average dip of 2° to the eastern upwarp. The axis of this eastern culmination trends N.20°E. In the northernmost part of this anticline, the axis plunges 4 to 6 degrees north. Towards the south the anticline becomes subdued and finally fuses with the western anticline into a large uplifted tableland, intensively dissected by creeks. Between the site of Haddon Downs homestead and Kuchumba Plain, most of the central part of the anticline has been eroded and only the extreme eastern limb has been preserved. It forms a very prominent ridge, about 16 miles long, on the west side of Haddon Creek. Trending in the general NNE.-direction, the beds exposed along this ridge show dips of 12° to 20°E. (see Fig. 5 and Pl. 1, Fig. 1).
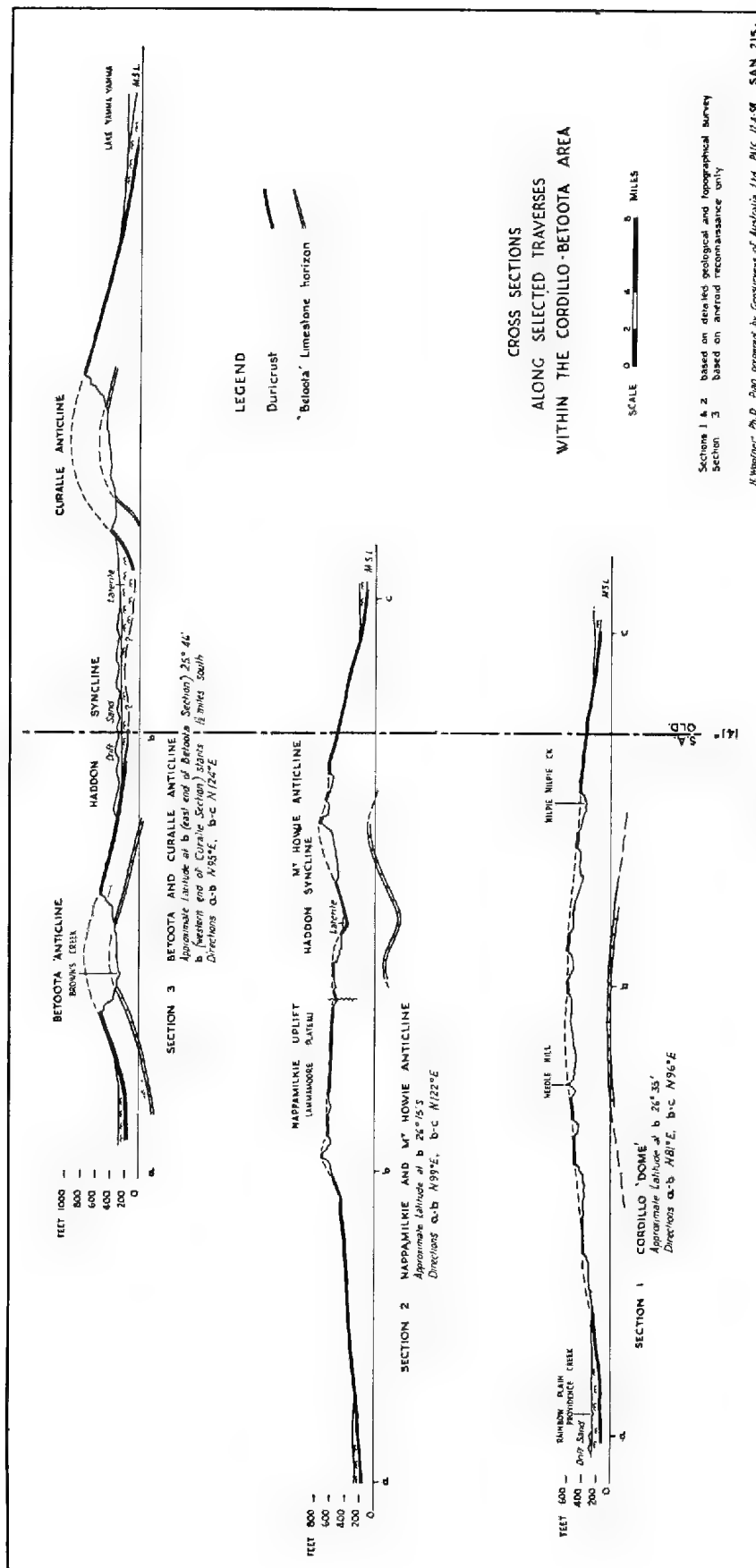
Fig. 3

This relatively steep dipping limb forms the eastern limit of the Nappa-milkie uplift. It dips into a well-developed structural depression, the *Haddon syncline*.

The Haddon syncline is strongly assymetrical. The western limb dips 12° to 20°E., whilst along the eastern limb an average dip of 2¼° to 4°W. is fairly persistent (see Fig. 3, Section 2, also Fig. 6). The axial trend is N.30°E. and shows a continuous plunge of 2°N. Due to the steady rise of the long axis towards the south, the Haddon syncline becomes less pronounced in its southern extension and flattens out completely after becoming level with the broad Cor-
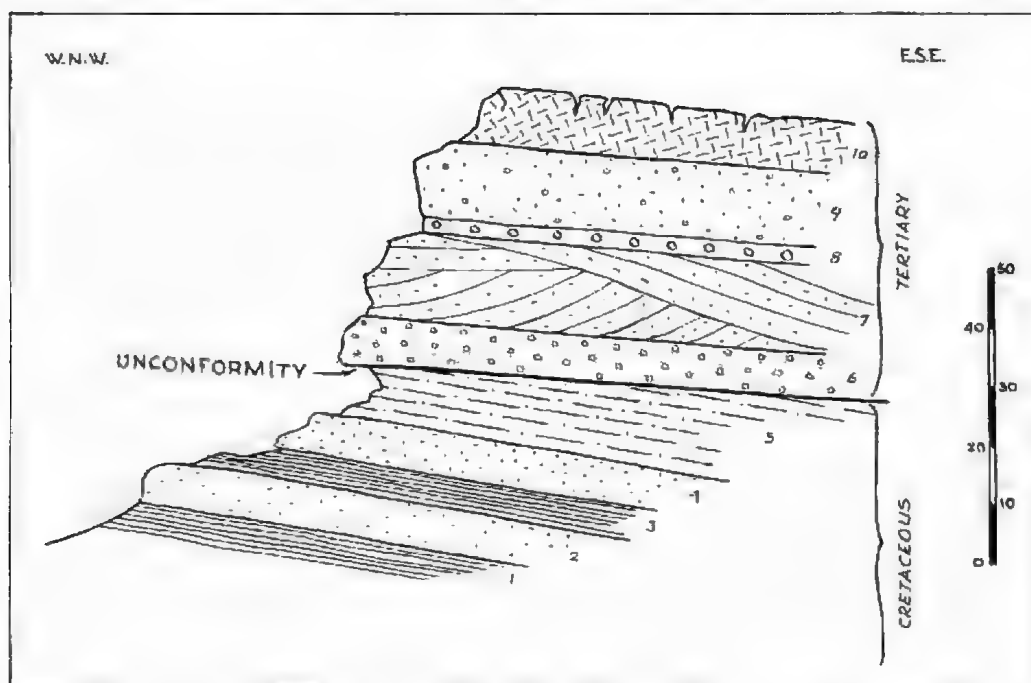


Fig. 4.—Scarp-section on the south-east limb of Morney dome showing angular unconformity between Cretaceous and Tertiary sediments.
Cretaceous (dip 6°): 1. White and purple shales; 2. White feldspatic sandstone; 3. White kaolinitic shale; 4. White feldspatic sandstone; 5. White kaolinitic silt-stone.
Tertiary (dip 4°): 6. Grey grit; 7. Fawn, coarse, torrential-bedded sandstone; 8. Pebble conglomerate; 9. Whitish to light brown gritty sandstone; 10. dense, highly silicified, coarse sandstone, "duricrust".

dillo uplift (see Fig. 2). This gentle rise to the south is very well demonstrated by the progressive surfacing of certain stratigraphic members, exposed along the centre of the valley of Haddon Creek.

A comparatively narrow, but distinct structure is developed east of Haddon syncline. It is called Mt. Howie anticline after the highest morphological point within the area occupied by it. Similar to the Nappamilkie uplift, the Mt. Howie anticline consists of a major anticline on the west, and a smaller, lower anticline on the east. The two anticlines are divided by a very shallow syncline (see Fig. 3, Section 2). The western limb of the main anticline dips 2° to 4°, the eastern limb about 3°. The eastern anticline has 1½° to 2° west-dip and about 3° east-dip. The long axis trends approximately N.30° to N.35°E. and plunges with 2° to the north, forming a good closure in the northern part of the struc-

ture. The north-plunge of the western anticline seems to be slightly steeper than that of the eastern anticline. Towards the south a minor local closure of about 50 feet might be present, but generally the Mt. Howie anticline fuses with the broad Cordillo uplift. The culmination of Mt. Howie anticline is reached in the vicinity of Mt. Howie (800 ft. M.S.L.) and the amount of structural relief is 440 feet in relation to the Haddon syncline and 550 feet in comparison with the plains south-east of the structure.

Neither the Nappamilkie uplift nor the Mt. Howie anticline have an obvious individual closure in their southern parts. They finally fuse together to the half-dome of the Cordillo uplift which forms the common closure for both of them towards south. This gives the whole structural unit the shape of a hand, four of its fingers spread out radially between north and north-east.

As mentioned previously, the western anticline of the Nappamilkie uplift forms a shallow closure at its northern end. This structural depression is also morphologically expressed. At the latitude of the border fence (near 10-mile gate) the eastern limb of this structure descends below the present plane of alluvial sedimentation and is hidden under alluvial clays and driftsand. Approximately 8 to 10 miles north of the border fence this eastern wing emerges from beneath the sand-dunes, and gradually gains elevation to form the eastern limb of the *Betoota dome* (see Fig. 2).

The Betoota dome is a simple, ellipsoidal-shaped dome with near "orthorhombic" symmetrical features. The trend of the long axis is about N.10°E. On either direction from the domal culmination, distinctive plunges of $1°$ to $2°$, slightly increasing towards the extreme northern and southern end of the dome, are observed. Both the western and the eastern limbs have dips of $3°$ to $5°$. In places, the dip on the western limb might be slightly more. Centrally, over about 4 to 7 miles in width, the roof of the Betoota dome has been eroded, leaving only two north-south trending cuestas on either side, nosing together at the ends. The cuesta which is built by the eastern limb, forms a west-facing escarpment, uninterrupted for nearly the whole length of the structure. The western limb, though also forming an escarpment, has been more deeply eroded and dissected, particularly in its northern half. This may indicate that the western limb of the anticline is slightly steeper-dipping than the eastern one.

On its extreme northern outcrop, the Betoota dome causes a deviation of Farrars Creek. This creek, previously following a south-westerly course, is deviated into a due easterly direction. On the north-western-most edge of the dome, the erosion by Farrars Creek has cut into the structure, isolating a few low, north-west dipping hills. After passing beyond the dome, Farrars Creek returns to its old course.

The length of the Betoota dome is about 35 miles, and the maximum width approximately 8 to 12 miles. The maximum structural relief of the dome (situated at a latitude of about 25°41′ to 25°45′S.) is 500 feet.

From the Betoota dome going east, driftsand and alluvial flats dominate the country. This type of country is very typical of structural depressions and persists for about 20 miles. It represents the northern extension of the Haddon syncline. As far as is known, this northern part of the Haddon syncline forms a wide, but rather shallow, trough, apparently with its long axis nearly horizontal. Minor warping parallel with the strike of the long axis could be present. North of Planet Downs a rise of the synclinal axis is indicated (see Figs. 2 and 3, Section 3).

To the east, the northern extension of the Haddon syncline is bordered by a row of low, NNE.-SSW. trending hills, which are the eroded remnants of the strongly dissected western limb of the *Curalle dome*. This dome is the most prominent structure within the whole area. It is situated north of the Mt. Howie anticline and continues in the same trend. Broadly speaking, the Curalle dome

is a simple, elongated structure broadening markedly in its northern extension. The general symmetrical features are "monoclinic". The surface expression of the structure is very good. The eastern limb, which dips at 2° to 7°, forms a large cuesta with a pronounced escarpment facing west and trending in a NNE.-SSW. direction. The maximum height of the scarp is 500 feet above the plain, in places possibly more. The maximum elevation is approximately 900 feet above M.S.L. This range is also known as Beal Range.

The western limb dips 12° to 23°W., the steepest dips being situated at about 26° south latitude. The strike along the southern part of the western limb is varying between N.5°W. and N.30°E. (see Pl. 1, Fig. 2 and Pl. 2, Fig. 1).

Two recently excavated water-dams, each situated just east of the strongly eroded remnants of the western limb provide excellent exposures of strata. Light grey coloured shales interbedded with carbonaceous shales exhibit the west-dipping structure very clearly. The dips are 14°W. in the southern exposure, and 10°WSW. in the northern one.

About 6 miles north-east of Planet Downs the strike of the western limb swings into a westerly direction (about N.40° to 50°W.), causing a considerable widening of the dome in the north. The dip also flattens to 2°-4°S. After continuing in this westerly strike for about 4 to 5 miles, the remnants of the western limb become covered by alluvial sediments.

In a manner similar to the western limb, the eastern limb also flattens in its northern part, and south of Lake Cuddapan shows a slight dip reversal from 2½°E. to 1½°W. It forms a small, strongly dissected hump and leads to a bulging of the limb towards the east. The final east-dip in this part is 1½° (see Fig. 2).

The long axis of the Curalle dome trends approximately N.30°E. and has an obvious plunge in its southern part. In its northern extension it is possible that the axis takes a more northerly trend. The northern plunge of the long axis is 2°. In its southernmost part, the Curalle dome flattens out slightly (limb-dips 2° to 3°) and finally plunges 2° south, forming a good closure towards the Mt. Howie anticline.

The overall length of the Curalle dome is about 40 miles. In the south the structure in outcrop is 10 to 12 miles wide, whilst in the northern part the width is between 14 and 18 miles. The maximum structural relief at the surface is at least 600 feet.

A shallow depression (approximately 250 feet) separates the Curalle dome from the *Morney anticline* which follows to the north (see Fig. 2). The Morney anticline is a huge ellipsoidal-shaped structure with slightly "monoclinic" symmetrical features. The limbs dip with 2° to 3° to the west and 2° to 6° to the east (see Fig. 4). The trend of the long axis is N.35°E. and the maximum structural relief about 500 to 600 feet. The Morney anticline is about 55 miles long and on its broadest part 30 miles wide.

Local drainage patterns have been strongly influenced by the geological structure. Here, as elsewhere in the basin, it is clearly evident that streams which originated on the steeper limb (having the steeper gradient) have the greater erosional energy. These creeks on the steeper limb of the structures were originally "consequent" streams, but in view of their greater erosional capacity, headwater erosion led to measure of encroachment and capture across the anticline. On most of the anticlines, the centre has been completely eroded out by these streams. Now they are superimposed streams, draining through narrow gaps in the remnants of the steeper limb (see Pl. 2, Fig. 1). They expanded their catchment areas well beyond the axis of the structure, capturing the headwaters of streams of the flatter limb. In several places one can observe the old creek-bed of deserted "consequent" streams of the flatter limb, filled with gravel and alluvial sand, dismembered from the opposite stream pattern on the escarpment which leads down to the drainage area of the creeks originated on the steeper dip slope.

The creeks on the flatter limb continue as consequent streams and usually retain shallow channels. For instance, on the Curalle dome, it has been estimated that about 80 per cent. of the area is drained toward the steeper western limb and only 20 per cent. toward the flatter eastern limb.

The big structural depressions, as, for instance, the Haddon- and the Farrars syncline, act as depositional troughs for the drainage systems of the broad uplifts. Debris from the structural highs still gets deposited in the structural lowlands (e.g. Rainbow Plain, Lake Cuddapan, Lake Yamma Yamma) which surround the anticlines.

Generally, the extensive control of the drainage pattern by the fold structures suggests comparative geomorphic youth of the structures.

## SUBSURFACE GEOLOGY

Very little subsurface information concerning all of these structures is yet available. Lockhart Jack (1925 and 1930) correlated all available bore information for the southern part of the area, but within the northern part of the structures only a few water bores have been sunk. These water bores only yield information on the position of the duricrust.
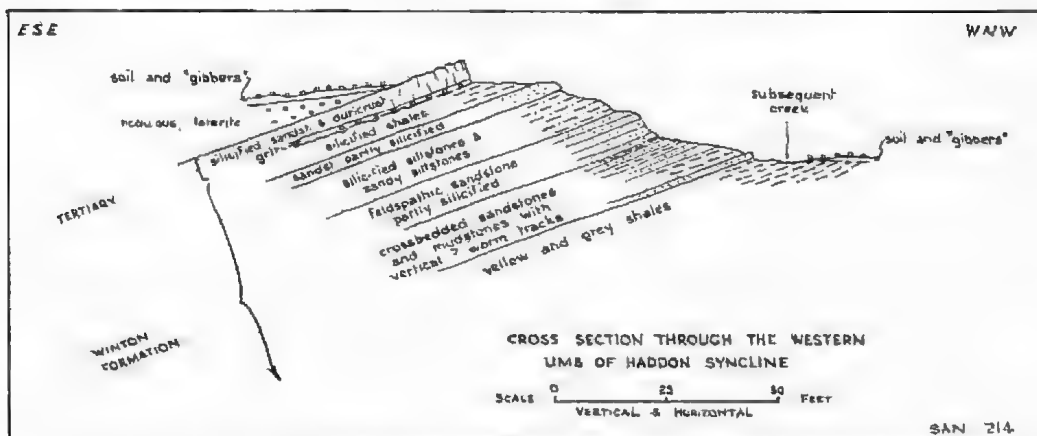


Fig. 5.—Section through the western limb of Haddon syncline (also eastern limb of Nappamilkie anticline), approximately six miles north of Haddon No. 4 bore, showing the stratigraphic sequence and the position of strata.

A few pastoral bores off the east limb of the Curalle dome show that the duricrust submerges underneath the present surface and consequently is now covered by "post-duricrust" sediments. Duricrust was struck at 100 feet below surface level in Long-Hole Well, situated on the eastern shore of Lake Cuddapan, and at 97 feet in Bloodwood Bore, 4 miles ENE. from Long-Hole Well. In Murphy's Bore, approximately 4 miles due north of Lake Cuddapan, duricrust was encountered at 50 feet. The continuation of the east-dip of the Curalle dome below the present surface level is further demonstrated by a few bores surrounding Lake Yamma Yamma. Apparently the duricrust reaches its deepest position on the north-side of the lake, where it is reported at a depth of 280 feet in Duck-Hole Bore.

To supplement surface observations, five shallow structural bores were drilled by SANTOS in 1957. The bores were drilled on the apex and on the

Fig. 6.

western limb of Mt. Howie anticline and across Haddon syncline. The position of bores Nos. 1 to 4 is shown in Fig. 6. Bore No. 5 is not shown in this plan and was situated about 4 miles south from No. 1. The bores proved the continuity of the particular structures to a depth of at least 750 feet (see Fig. 6).

As a marker horizon, the uppermost section of the "Betoota" Limestone horizon was used. As mentioned previously, this zone has a very widespread occurrence for it is exposed in the centres of the Betoota and the Curalle domes as well as in the centre of the Morney anticline.

The calcareous beds occur at an average stratigraphic depth of 700 feet and are interbedded with green, friable, medium-grained sandstones. The thickness of the individual limestone bed varies between 6 inches and 2 feet 6 inches, and usually two to four limestone beds were struck. The author is aware of the possibility that some of the thinner calcareous beds might be only lenses with limited lateral extension, but the whole zone itself represents a type of sedimentation with definite calcareous tendencies, far more than normal for the dominantly clastic sediments of the Winton Formation. According to an analysis, carried out by R. Grasso, Geosurveys of Aust. Ltd., the hard calcareous beds have an average composition of 47 per cent. calcium carbonate, 33 per cent. pelitic material and 20 per cent. fine-psammitic material. Due to a high content of dark minerals in the sand-fraction (mainly hornblende and biotite), these sandy limestones have a rather unusual and characteristic appearance.

A second marker horizon, a hard pyritic pelite, was struck between 1352 feet and 1357 feet in No. 1 bore and between 938 feet and 942 feet in No. 5 bore. This sediment is built up of minute, interlocking crystals of pyrite suspended in a very fine-grained clayey matrix. Both No. 1 and No. 5 bores are situated on the crest of Mt. Howie anticline and the different position of the pyritic band corresponds with the north plunge of the anticlinal axis of 1½ to 2 degrees.

A preliminary seismic survey, undertaken by the Bureau of Mineral Resources, showed that at least the east-dip of the same structure is still present at a depth of 6500 feet (Smith, 1958).

## DISCUSSION

Concerning the origin of these structures, consideration of the nature of the sedimentary system comprising the basin is essential. The Great Australian Artesian Basin, as a Mesozoic structure, was an epicontinental development which has experienced no orogenic deformation.

In marginal areas, reflected structures due to sedimentary "draping" effects over old, pre-Mesozoic morphological highs are quite common. Examples of reflected structures have been observed along the Peak and Denison Ranges and recently at Oodnadatta (Wopfner, 1957). This explanation can hardly be applied to the structures described above, situated in the cental part of this deep basin. The seismic survey by the Bureau of Mineral Resources, for example, indicates probably 8000 feet of Mesozoic sediments in the Haddon syncline (Smith, 1958). Such a thick sedimentary blanket would even out all but the most extreme morphological features of buried old relief. Rather it is felt, it must be assumed that the only forces which could create structures of the observed type within this part of the Great Australian Artesian Basin, would be of the *epeirogenetic* type.

Epeirogenetic forces could have acted either as normal uplifts or as differential movements along planes of dislocation both in vertical and/or transcurrent direction. As regards these latter possibilities, pre-existing dislocation planes in the basement could have been re-activated, with the movements transferred to the overlying younger sediments.

While the movements within the more rigid rocks of the basement would be expressed in straight dislocation planes (vertical or horizontal) the overlying, more pliable Mesozoic rocks (in particular the Cretaceous) would tend to absorb some of these stresses; e.g. a normal fault in the basement would be extensively modified and/or compensated through the several thousand feet of overlying sediments, and be expressed on the surface by a monoclinal fold. Depending on the type of movements and their directions, various patterns of deformation can be predicted. The morphology of the contact between the rigid "basement" and the pliable "basin" sediments, and also internal inhomogeneities within the pliable sedimentary body itself may also influence the final structural pattern.

For the following reasons, i.e. the epicontinental character of the Great Australian Artesian Basin, the gathering of the axial trend within the northeast sector and the en-echelon arrangement of the anticlinal axes (see Fig. 2), the author favours transcurrent movements as having been the cause of the fold-structures. Though he realises that the stage of our knowledge on this particular matter is still incomplete and sketchy, he would like to present the following working-hypothesis for discussion.

Transcurrent movements within the basement following a general northeast, south-west direction with the north block translated relatively to the northeast, would introduce a rotational strain that could produce the present structures. Within the rigid basement this shearing strain would develop two sets of shearing planes. One of these sets lies closer to the direction of the shearing couple than the other, and the main slip would occur along these planes (in our case approximately N.70°E, initial stage).

As the thick blanket of Mesozoic sediments is weaker and much more pliable than the "basement", it reacts differently upon deformation. Instead of developing differential shearing planes, folding occurs in en-echelon pattern, whereby the axial trend lies at a right angle to the direction of maximum compression. The maximum compression will be perpendicular to the longest axis of the strain ellipsoid. (A very rough experiment, whereby a layer of putty was sheared on two boards, produced folds nearly identical with the structures concerned. The experiment was repeated several times and yielded the same results each time.)

In the initial stage the axis of the strain ellipsoid is approximately 45° to the direction of the shearing couple (in our case about north), but as the amount of transcurrent movement increases the angle between the direction of the couple and the longest axis of the strain ellipsoid becomes more acute. It may be assumed, therefore, that the structures with the closest trend to north are those which were initiated first, while the anticlines with more north-easterly trend originated at a later stage. If this hypothesis is correct, it would mean that the Nappamilkie and the Betoota anticlines are those which were initiated first. Following this first stage of warping the developing anticlines presented a more rigid body than the surrounding unwarped sediments. Therefore, the originally established trend remained constant, even the amount was still increasing and the longest axis of the strain ellipsoid moving constantly east of north. With continued movement, other parts of the sediments were folded but along a more easterly trend (Mt. Howie, Curalle and Morney anticline), while the southern extensions of both anticlinal lines fused together to the Cordillo half-dome.

In the marginal areas of the basin the sedimentary cover of the basement was too thin to compensate the shear movements and single shear planes may be expected to pass through into the Mesozoic sediments. The foregoing out-

line would presumably explain the restriction of actual folding of cover sediments to the central, thicker portion of the Great Australian Artesian Basin.

There are several reasons for selecting north-east, south-west transcurrent movements. Firstly, this is the most favourable direction to explain the observed trend of the anticlines. Secondly, the north-east, south-west direction is a preferred direction of geological features, not only within the Great Australian Artesian Basin itself, but also within its surrounding older rocks.

The age of the folding can only be established within a rather wide time-limit. At the stage of our present knowledge we have to assume that the sediments of the Winton Formation have been deposited in the lower Upper Cretaceous, most probably in Cenomanian time. The Winton is overlain disconformably by grits and torrential bedded sandstones thought to be Lower Tertiary in age.

The Tertiary sediments are usually most prominently developed on the limbs of the anticlines and towards the synclines. In several instances the Tertiary wedges out completely towards the crest of the anticlines. Within the area described by this paper the Tertiary beds are folded disconformably (unconformably in the case of Morney anticline) with the underlying sediments of the Winton Formation.

The oldest, unfolded beds, following on top of the Tertiary grits and sands (usually "duricrusted") are laterites and lateritised sands. These, in turn, are overlain by travertines, alluvial clays and silts and sand-dunes. The travertines and sand-dunes are considered to be of Quarternary age which would suggest that the laterites are of late Tertiary age. Assuming that the dating of the grits and torrential bedded sandstones as Tertiary is correct, the above-mentioned observations would give evidence that the folding movements have been initiated not later than in Upper Cretaceous time (post-Cenomanian).

Subsequently, the Cretaceous sediments were exposed to erosion, but became covered again, this time by fresh-water lakes, and the coarse Tertiary grits and sandstones were deposited. While this sedimentation was still well in progress, folding movements were renewed and probably reached a climax in late Eocene to Oligocene time.

Together with vertical uplifts, this last phase finally displaced the water cover into large depressions whereof Lake Eyre, Lake Gregory and several other low-lying salt pans are the last remnants.

## ACKNOWLEDGMENTS

Fig. 1.—The western limb of the Haddon syncline about one mile north of Haddon No. 4 bore, looking south. The top layers are strongly silicified. Dip 15°E. (Photo H. Wopfner.)



Fig. 2.—Part of the western limb of Curalle dome, north of Coppacunda Well, looking south. Dip 16°W. (Photo H. Wopfner.)

Fig. 1.—The strongly eroded western limb of the Curalle dome seen from the air. The widening of the dome towards north can be clearly observed in the top left of picture. The high scarp, built up by the eastern limb of the anticline (Beal Range), is in the right far background. Direction of view, NNE. (Photo H. Wopfner.)

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# NOTES ON THE GENUS EUCALYPTUS IN SOUTH AUSTRALIA

*BY* C. D. BOOMSMA

**Summary**

A revision is made of the geographical locations of a number of species of the genus eucalyptus in South Australia.

# NOTES ON THE GENUS EUCALYPTUS IN SOUTH AUSTRALIA

By C. D. Boomsma[*]

[Read 13 August 1959]

## SUMMARY

A revision is made of the geographical locations of a number of species of the genus eucalyptus in South Australia.

## INTRODUCTION

Owing to the amount of clearing for agricultural settlement that has taken place of recent years in South Australia, it is almost inevitable that many of the original occurrences of trees of the genus eucalyptus will eventually be known from the records only, rather than from actual sites. The following notes deal with new observations on the geographical occurrence of a number of species of the genus.

Of recent years very little material, if any, has been collected in South Australia of *E. eudeomoides*, *E. ewartiana*, *E. gongylocarpa*, *E. pachyphylla*, *E. oldfieldii*, and *E. viridis*.

*E. albens* Miq.
> Only two trees have been located near Wirrabara township, in the type area, which agree with the type description. However, there are many which agree with the description of *E. hemiphloia*, amongst the commonly occurring greybox, *E. microcarpa*. It has been suggested by Pryor (personal communication) that mixed type material formed the basis of the description of *E. albens*.

*E. anceps* (R. Br.) Blakely
> On the south side of Torrens Gorge, Hd. Onkaparinga, approximately three miles east of Athelstone, a small outlier of 10-12 stems. C. Boomsma, 1947.

*E. baxteri* (Benth) Maiden and Blakely
> 1. A stunted small tree to 30 ft. high, mature leaves with long acuminate point, bud has a conical operculum, and typical exsert valves to capsule. Mt. Kitchener, R. V. Woods, 1954 (personal communication). This may be the most northerly occurrence of this species.
> 2. A stunted small tree to 30 ft. high, Sec. 42, Hd. Waitpinga, now cleared. Mature leaf wider and thicker than type, fruit larger than type, 15 mm. × 15 mm. C. D. Boomsma, 1950.

*E. behriana* F. v. M.
> Collections were made from Curtwillia Creek, Cowell, D. Smith, 1956; Wanilla, W. C. Johnstone, 1956; Stockport in the lower north, C. D. Boomsma, 1957; and Mt. Woodforde, the far north, J. J. Johnson, 1955.

*E. calycogona* Turcz
> Small island inliers, Sec. 140, Hd. Howe, Southern Flinders Ranges. C. D. Boomsma, 1949.

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[*] An officer of the Woods and Forests Department.

## E. camaldulensis Dehn

Although a generalised occurrence by Burbidge in Trans. Roy. Soc., 1947, includes "water courses throughout S.A.", and by Black, 1957, includes "all over S.A. except the dry creekless area north of the Great Bight", an area of 20 acres, half mile east of Minlaton, Boomsma, 1949, is the only known occurrence on Yorke Peninsula, and a larger area occurs at Polda, Eyre Peninsula, in the Hds. Squire, Tinline and Ulipa, R. French, 1956 (personal communication).

## E. cladocalyx F. v. M. (Figs. 3 and 4)

Three genetic variants showing some characteristics of E. camaldulensis and E. cladocalyx were noted in Chapmans Gums Swamp, Wanilla, Eyre Peninsula, W. C. Johnstone, 1951; C. D. Boomsma and Pryor, 1958.
The form and shape of E. cladocalyx varies in the three areas of natural occurrence, very crooked to stunted tree to 35 ft. high on Eyre Peninsula; with an improvement in straightness and increase in height on Kangaroo Island to tall shaft-like trees to 90 ft. high in the Southern Flinders Ranges. No natural stands have been found agreeing with the description of the horticultural variety nana.

## E. cneorifolia D.C.

1. Two small ridge top outliers on lateritic soil in Sec. 381, Hd. Encounter Bay, have now been cleared.
2. A recently observed occurrence nearby on a friable sandy soil 5 miles south-west of the Back Valley P.O. on Rivington Farm. J. G. Wood, 1959; in the University of Adelaide, Herbarium.

## E. concinna Maiden and Blakely

Along the E.-W. transcontinental railway line, Whynbring, J. Johnson, 1955.

## E. cosmophylla F. v. M.

In areas between two associations, E. obliqua and E. cneorifolia, on Kangaroo Island, and E. obliqua and E. fasciculosa on Fleurieu Peninsula, specimens with more than three buds per umbel, and atypical bud characters. C. D. Boomsma, 1947.

## E. dumosa A. Cunn

Smooth budded specimens are found in eastern localities of South Australia, but specimens which are not smooth budded are usually referable to other species.

## E. elaeophora F. v. M.

Small tree to mallee, 10-15 ft. high, on the upper slopes and summit of two peaks in Elders Range surrounding Wilpena Pound. G. Gross, 1953, and R. French, 1957 (personal communication); I. Brooker, 1958.

## E. gamophylla F. v. M.

While this species is best known by its perfoliate juvenile foliage, the intermediate foliage, not often seen, is sessile, to shortly petiolate, opposite, to alternate and lanceolate $1 \cdot 5 - 2$ cm. $\times 4 - 6$ cm. Mature foliage not seen. Mann Ranges, J. Johnson, 1955.

## E. gillii Maiden

No specimens have been located by me, in the vicinity of Wirrabara during the period 1945-1958 which is in the type area. Its most southerly occurrence appears to be Biblianda Station. J. Johnson (personal communication).

*E. intertexta* R. T. Baker
Mature foliage, robust, coriaceous, ovate-lanceolate 7-10 cm. × 2·5 — 4 cm. fruits about twice normal size. Mt. Moulden, Blyth Ranges, J. Johnson, 1955; R. L. Crocker, 1956.

*E. jugalis* Naud
Probably a "nomen dubium", Pryor (personal communication), but not *E. leucoxylon var. pauperita,* J. E. B. Throughout the high rainfall parts of the Southern Flinders Ranges, scattered individuals or small groups up to 50 trees having intermediate characteristics between a box and a gum. They could be genetic variants of *E. leucoxylon* and a box, the common box is *E. microcarpa.* C. D. Boomsma, 1947.

*E. largiflorens* F. v. M.
Several restricted disjunct occurrences either on swamps or along flood plains to water-courses far removed from the large occurrence along the Murray River. Mingary Creek, Oakvale Station, and Kalkaroo. J. Johnson, 1953; Halbury, C. D. Boomsma, 1956.

*E. macrorryncha* F. v. M.
A genetic variant, a single tree with level valves to the fruit. Sevenhills. Pryor and Boomsma, 1953.

*E. microtheca* F. v. M.
Large broad-lanceolate foliage, Everard Park. J. B. Cleland, 1954. A number of specimens with enclosed valves examined by L. Johnstone, 1958, were stated to be genetic variants of *E. microtheca.* Mann Ranges, J. Johnson, 1955.

*E. obliqua* L'Herit
Stunted tree to mallee-like, 10 ft. high, fruit with level, to exsert valves. Ridge Road, Parawa, C. D. Boomsma, 1946.

*E. odorata* Behr and Schl.
Lanceolate to ovate-lanceolate intermediate foliage predominates on trees on the west facing lower slopes of the Mt. Lofty Range, while the lanceolate to narrow lanceolate mature foliage is characteristic of the northern areas to form variety *angustifolia,* Blakely

*E. oxymitra* Blakely
Widespread in the vicinity of the far north-western ranges, J. Johnson, 1955; R. Crocker, 1956 (personal communication).

*E. pauciflora* Sieb
Genetic variants from Sec. 574 Hd. Caroline, N. Lewis, 1952.

*E. pileata Blakely*
Occasional specimens have been collected from the far north, J. Johnson, 1955; R. Crocker, 1956 (personal communication).

*E. pyriformis* Turcz
Fruits nearly smooth, Bulgunnia Station, J. Johnson, 1952.

*E. rubida* Dean and Maiden
A disjunct occurrence of only a few acres in Sec. 304 Hd. Yankalilla. It is adjacent to the *E. obliqua* and *E. fasciculosa* associations. C. D. Boomsma, 1947.

*E. rugosa* R. Brown and Blakely
Hybrid swarms in the Hundred of Coonarie, Yorke Peninsula; and Fishery Bay, Eyre Peninsula. C. D. Boomsma, 1947; and Boomsma and Pryor, 1958.

*E. terminalis* F. v. M.

The forms with narrow lanceolate mature leaves, and ovate-globular thick walled fruits with a constricted orifice, usually only a few per umbel at maturity, are referable to *E. dichromophloia* F. v. M., L. Johnstone, 1958. Observed by J. Johnson in Musgrave, Mann and Tompkinson Ranges.

*E. uncinata* Turcz

Because specimens are rarely collected, if at all, in South Australia, this species could be regarded as endemic to Western Australia.

*E. viminalis* Labill (Figs. 1 and 2)

The rough barked coastal form has been known to occur on Eyre Peninsula since 1951, but verification was not made until 1958 by Pryor and Boomsma. The occurrence is typical for the species being confined to the lower slopes and bottoms of valleys in undulating country on terra-rossa soils. Several hundred trees were seen distributed over Mickera Station, Hd. Sleaford, where it is known as the Mickera Gum.

*E. vitrea* R. T. Baker

Is now regarded to have a hybrid origin, so it is not surprising to record a wider range of characters than in the original description. L. Johnstone, 1952; Pryor, 1955 (personal communication).

*E. websteriana* Maiden

A new record for South Australia. Single specimen of three dozen mature leaves, eight buds and one capsule. Mature foliage bunched together, sub-glaucous, ovate, obovate to obcordate or emarginate. Petioles, young branchlets, peduncles and pedicels glaucous. Buds and inflorescence agree with the original description. Capsule larger, $14 \cdot 0 \times 0 \cdot 8$ mm., broad disc gently rising to the base of the small triangular exert valves. Mt. Wood-roofe, 3,000 feet altitude. J. B. Cleland, 18/4/59, State Herbarium 95, 951, 132. Determined by S. T. Blake, 18/6/1951. Maiden refers to cultivated seedlings ex Tarcoola blocks P. 381, Vol. VIII, Pt. 5.

*A New Record for South Australia*

A mallee, mature leaves somewhat oblong-lanceolate, widely spaced, al-ternate, long acuminate point, petiolate, and venation indistinct, size 7-8 cm. $\times 1 \cdot 1 - 1 \cdot 8$ cm. Fruit shortly pedicellate, axillary umbels, on short compressed peduncle, cupular shape 7 mm. $\times$ 7 mm. with raised rim 2 mm. wide, valves short, exserted and subulate. J. Johnson, 1955; R. Crocker, 1956; Lothian and Hill, 1958.

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Fig. 2.—*E. viminalis* (coastal form). Yankalilla, Fleurieu Peninsula, Sept., 1958.



Fig. 1.—*E. viminalis* (coastal form), showing rough box-like bark and grossly crooked form similar to Fig. 2. Mickera, Eyre Peninsula, Sept., 1958.

Fig. 4.—*E. cladocalyx* self-sown seedling, showing abrupt taper and forked stem. Wanilla, Eyre Peninsula, Sept., 1958.



Fig. 3.—*E. cladocalyx*, savannah woodland formation associated species in the understory are *Xanthorrhoea semiplana*, *Hibbertia stricta* and grasses. Wanilla, Eyre Peninsula, Sept. 1958.

# CONTRIBUTIONS TO THE FLORA OF CENTRAL AUSTRALIA NO. 1

*BY* G. M. C*HIPPENDALE*

### Summary

A new name is proposed, *Borreria hillii* (syn. *Spermacoce scabra* Ewart). Amended descriptions are given for two species, *Bassia spinosa* Ewart *et* Davies and *Eucalyptus gongylocarpa* Blakely. Additional notes are given for several species, and ten species including two naturalised species are given as new records for Central Australia.

# CONTRIBUTIONS TO THE FLORA OF CENTRAL AUSTRALIA
## No. 1

### By G. M. Chippendale[*]

### [Read 8 October 1959]

## SUMMARY

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Amended descriptions are given for two species, *Bassia spinosa* Ewart et Davies and *Eucalyptus gongylocarpa* Blakely.
Additional notes are given for several species, and ten species including two naturalised species are given as new records for Central Australia.

### Isoetaceae

*Isoetes muelleri* A. Br. Top of Ayers Rock in rock pool, D. E. Symon, 14/6/1953 (ADW 9715).

This is a new record for Central Australia, and was brought to my notice by Mr. David Symon.

### Gramineae

*Eriachne armitii* F. Muell. This species was omitted accidentally in the Check List in last year's Transactions (Chippendale, 1959).

### Proteaceae

*Hakea arborescens* R. Br. One mile east of Kurundi H.S., Neville Forde, 11/5/1957 (NF 821). A new record for Central Australia.

### Chenopodiaceae

*Bassia spinosa* Ewart et Davies. Subshrub to 30 cm. high, grey, tomentose with branching hairs on stems and leaves, branches often tangled, more or less procumbent. *Leaves* sessile, narrow, oblanceolate or obtuse, 10 mm. to 14 mm. long, 2 mm. to 2·5 mm. wide near apex. *Flowers* solitary, axillary. *Fruiting perianth* tube 2 mm. long, attached firmly to stem, mostly with 4 spines, one to 4 mm. long, two shorter divergent at base, the fourth spine often shorter again. *Seed* vertical or slightly oblique to summit of perianth.

Lander Creek, G. F. Hill, 15/6/1911 (G.F.H. 346, Holotype, seen on loan from Melbourne Herbarium), 10 miles east of Central Mount Wedge H.S., R. E. Winkworth, 1/7/1954 (Herb. Aust.[†] REW 383). Five miles east of Alice Springs, R. A. Perry, 5/3/1953 (Herb. Aust. RAP 3232). Twenty-five miles west of Haast Bluff Settlement, R. E. Winkworth, 9/6/1954 (Herb. Aust. REW 317). Fifteen miles south-west of Alice Springs, R. E. Winkworth, 7/5/1954 (Herb. Aust. REW 262). Three miles south of Angas Downs, M. Lazarides, 9/10/1956 (Herb. Aust. ML 6183).

The above is an amended description, as the species is not well known, and was not seen by R. H. Anderson at the time of his revision of the genus *Bassia* (1923). Examination of fragments of the holotype showed that G. F. Hill's specimen was affected by insects, and it was these affected parts which were

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[*] Botanist, Animal Industry Branch, Department of Territories, Alice Springs, N.T.

[†] The official abbreviation for the herbarium in Canberra, cited as "Herb. Aust.", is CANB.

described by Ewart and Davies as "fruiting perianths connate into a hard mass of about half-inch diameter". Mr. Burns and Mr. Neboiss of Melbourne Museum agree that the hard masses are "indeed galls caused by insects, possibly flies".

The affinities of this species are with *B. quinquecuspis* F. Muell., and not with *B. paradoxa* (R. Br.) F. Muell. as originally stated by Ewart and Davies. It is sometimes a common species in mulga scrub, and is also found on some low calcareous hills, and in sandy soil on eroded flats with scalded patches.

### AIZOACEAE

*Trianthema rhynchocalyptra* F. Muell. Twenty-four miles south of Barrow Creek township, R. A. Perry, 3/9/1955 (Herb. Aust. RAP 5350).

This is a new record for Central Australia, and the collector's note states "prostrate mat plant, with pink flowers".

### PAPILIONACEAE

*Daviesia chordophylla* Meissn. Twelve miles north-east of Narwietooma H.S., M. Lazarides, 15/9/1956 (Herb. Aust. ML 5991). A new record for Central Australia.

### MIMOSACEAE

*Acacia torulosa* Benth. Four miles north of Wauchope, Neville Forde, 8/11/1956 (NF 695). A new record for Central Australia.

### CAESALPINIACEAE

*Cassia curvistyla* J. M. Black. 14·2 miles south-east of Tanami, G. Chippendale, 3/5/1958 (NT 4267); 17 miles north-east of Lake Mackay, G. Chippendale, 17/6/1957 (NT 3412).

These recent records, together with the two localities quoted by Black with his original description (1938) help to show the distribution of this little-collected species. These records were all in sandy soil in *Triodia* sp. communities, in one case in lateritic sand, and in one other case in an area of burnt *Triodia* sp. It seems most likely that this species extends over most of the arid area north and south of Tanami.

### ZYGOPHYLLACEAE

*Zygophyllum iodocarpum* F. Muell. Twelve miles south-west of Tempe Downs H.S., M. Lazarides, 4/10/1956 (Herb. Aust. ML 6120). This is a new record for Central Australia, with the collector's note: "common in undulating area with low hills and *Acacia estrophiolata*".

### EUPHORBIACEAE

*Petalostigma quadriloculare* F. Muell. var *nigrum* Ewart et Davies. Five miles north of Kurundi Station, M. Lazarides, 28/8/1956 (Herb. Aust. ML 5866). Five miles south of Wauchope, R. E. Winkworth, 21/3/1955 (Herb. Aust. REW 962). Two miles north of Wauchope, R. E. Winkworth, 22/3/1955 (Herb. Aust. REW 979). Ten miles north of Murray Downs H.S., R. E. Winkworth, 29/7/1954 (Herb. Aust. REW 522). Seventeen miles west of Rockhampton Downs turn-off, Barkly Highway, G. Chippendale, 14/8/1955 (NT 1533). Forty-one miles south of Wave Hill H.S., G. Chippendale, 11/7/1956 (NT 2204). Muckaty turn-off, Stuart Highway, G. Chippendale, 11/3/1955 (NT 1075).

The description of this variety by Ewart and Davies states: "Fruit black, ¼-inch diam., glabrous, seeds smooth, dark brown". Examination of fragments of the varietal types seen on loan from Melbourne Herbarium showed that all

of the above specimens were vegetatively identical with these types. A suggestion that the original description of the fruit of this variety may be faulty was checked at Melbourne Herbarium by Miss H. Aston, and it seems clear that the descriptions were made from fruits which were not in a perfect state. The blackness was due to age, as was also the glabrousness. There were no collector's notes. In the specimens quoted above, the fruit is quoted in the field as being "apricot-yellow" and "orange-yellow", and the capsule is silky pubescent when immature, and appears to lose some of this pubescence with age. A further specimen in Melbourne Herbarium, matching G. F. Hill's No. 387, collected by J. McDouall Stuart, North Australia, lat. 20°20′, had a collector's note stating, "Small, bitter, orange-coloured fruit".

This species is sometimes known as Strychnine Bush in the Northern Territory.

## MALVACEAE

*Sida platycalyx* F. Muell. ex Benth. Fl. Aust. i.197. 1863.
Synonyms:
*S. inclusa* Benth. Fl. Aust. i.197. 1863.
*S. podopetala* F. Muell. et R. Tate in Trans. Roy. Soc. South Australia, 13, 94-109. 1889-1890.
*Abutilon pedatum* Ewart in Ewart et Davies Fl. Northern Territory, p. 182. 1917.

The case for the synonymy of *S. inclusa* was accurately made by White (1922). In the case of *S. podopetala*, the authors separate it as having "narrower leaves, by the calyces being not provided with very prominent ridglets and further by the petals emerging beyond the calyx". In describing *S. platycalyx*, Bentham states: "Petals broad, shorter than calyx", but more than likely he did not see adequate material. He only quotes "Sturts Creek". In dried specimens, the buds of this species sometimes give the impression of being mature flowers, but in the field the species varies greatly in the size of leaves on the same plant, and also according to season conditions and habitat. The petals are at length longer than the calyx. The ridges on the calyces is also a variable factor. Tietken's specimens from Glen Helen, June, 1889, and Warman Rocks, 10/6/1889, and a specimen from Ilpilla Gorge, James Range, were examined on loan from Adelaide Herbarium.

A type of *Abutilon pedatum* seen on loan from Sydney Herbarium had been correctly determined by Miss Neridah Ford as *S. platycalyx*.

## MYRTACEAE

*Eucalyptus gongylocarpa* Blakely. Near King Creek, 23½ miles south of George Gill Range, G. Chippendale, 27/6/1959 (NT 6326). Twenty-eight miles north of Lake Amadeus, G. Chippendale, 28/6/1959 (NT 6343). Sandy slope at Lake Amadeus, G. Chippendale, 29/6/1959 (NT 6390). Ten miles southwest of Glen Edith, G. Chippendale, 24/6/1959 (NT 6274).

No description of the buds of this species appears in literature, and the following description is made from the above specimens:

*Umbels* axillary, slightly deflexed, 3-9 flowered, but mostly 4-7 flowers, peduncles terete 10-15 mm. long, *buds* pruinose 3-3·5 mm. diameter, *pedicels* 4-6 mm. long, *operculum* hemispherical, truncate at summit with faint radiating ridges, 1·0-1·6 mm. high, *tube* short conical 2·0-3·5 mm. mostly 3·0-3·5 mm. long.

This species is common in aeolian sands in *Triodia pungens* associations which are west of the settled areas in Central Australia.

## SOLANACEAE

*Solanum melanospermum* F. Muell.  Stirling bore, 20 miles south of Barrow Creek Township, R. A. Perry, 3/9/1955 (Herb. Aust. RAP 5349).  This is a new record for Central Australia.

## RUBIACEAE

### *Borreria hillii* nom. nov.

*Spermacoce scabra* Ewart in Flora of the Northern Territory, p. 260, 1917. Ewart's specific epithet had been used previously in *Borreria* by K. Schum., 1895.

## CUCURBITACEAE

*Cucumis myriocarpus* Naud.  Temple Bar Creek, eight miles south-west of Alice Springs, G. Chippendale, 22/1/1959 (NT 5327).  This is an addition to the naturalised plants of Central Australia.

## COMPOSITAE

*Vernonia cinerea* (L.) Less. var. *lanata* Koster in Blumea I No. 3 (1935), 408. This was recorded as *V. cinerea* in last year's Transactions (Chippendale, 1959).

*Erigeron bonariensis* L., Alice Springs, G. Chippendale, 3/4/1958 (NT 4151). This is an addition to the naturalised plants of Central Australia.
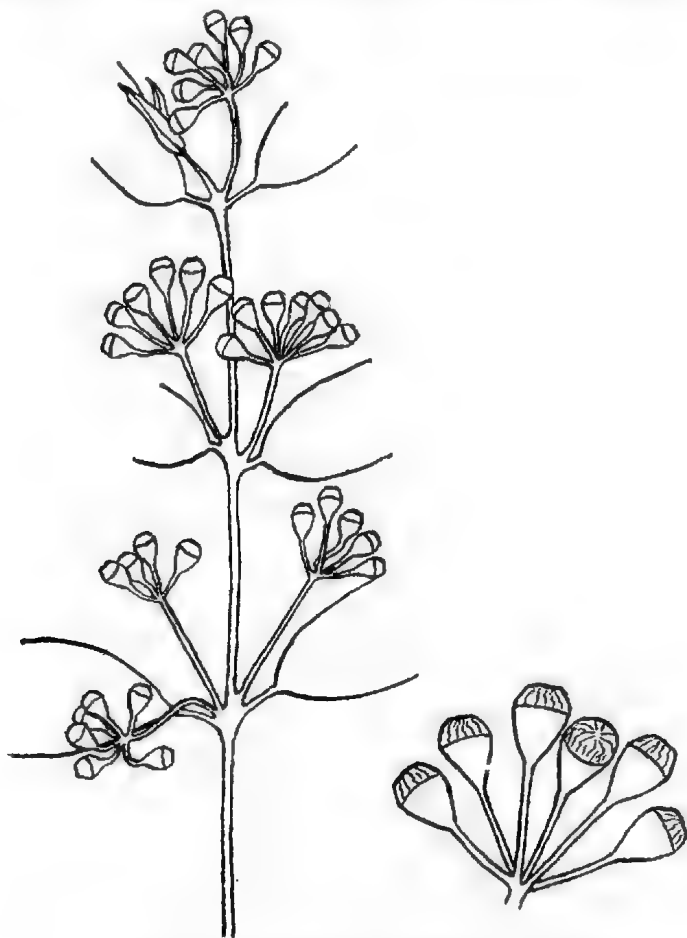


Fig. 1.—Buds of *Eucalyptus gongylocarpa* Blakely.
(Twig is natural size.)

## ACKNOWLEDGMENTS

## REFERENCES

ANDERSON, R. H., 1923.  Proc. Linn. Soc. N.S.W., xlviii, part 3 (1923).  "A Revision of the Australian Species of the Genus *Bassia*".
BLACK, J. M., 1938.  Trans. Roy. Soc. S. Aust., **62** (2), p. 354.  "Additions to the Flora of South Australia, No. 37".
CHIPPENDALE, G. M., 1959.  Trans. Roy. Soc. S. Aust., **82** (1959), pp. 321-338.  "Check List of Central Australian Plants".
EWART, A. J., and DAVIES, O. B., 1917.  The Flora of the Northern Territory.
WHITE, C. T., 1922.  Queensland Agric. Journal, 17-18 (Jan., 1922), 34-5.  "A Western Burr".

# HENRY KENNETH FRY, D.S.O, M.D., B.SC., DIP.P.H.
## 1886-1959

**Summary**

## HENRY KENNETH FRY, D.S.O., M.D., B.S., B.SC., DIP.P.H.
### 1886-1959

H. K. Fry was elected a member of this Society in 1923, became a member of its Council from 1933 to 1938, and was President for the last year of this period.

Dr. Fry graduated at the University of Adelaide in Science in 1905 and in Medicine in 1908. In 1909 he was awarded the Rhodes Scholarship and proceeded to Oxford, where he gained the B.Sc. degree in 1912 and the Diploma in Public Health. His post-graduate study was in the subject of Anthropology.

Returning to Australia in 1913, he joined the Northern Territory Health Service and in the Territory found an outlet for his training in anthropology through his interest in the Australian aboriginal.

After serving for some time in the far north, he took up private practice but continued in his academic leanings and in 1934 gained his degree of M.D. in the University of Adelaide and was also made a Fellow of the Royal Australian College of Physicians. During the later years of his life, he served as Medical Officer of Health for the City of Adelaide.

Dr. Fry always maintained an active interest in anthropology and for many years was a member of the University Board for Anthropological Research. He took part in a number of University field expeditions to Central Australia — including those to Hermannsburg, Cockatoo Creek, Mount Liebig, the Granites, Ernabella and Yuendumu. He was especially interested in social anthropology and made a special study of some aspects of the social structure of Central Australian tribes, on which subject he published a number of recognised authoritative papers.

Most of his anthropological papers are contained in the Transactions of this Society, his main works being:

    1931  A table showing the Class Relations of the Aranda.

    1932  Genealogical studies of Australian tribal systems.

    1934  Kinship and descent among the Australian aborigines.

    1950  Aboriginal Social Systems.

A major anthropological contribution, "Fear in Primitive Society", was published by the Anthropological Society of South Australia as No. 1 of its Occasional Publications (1938). He was among the foundation members of this Society.

Kenneth Fry will always be remembered for his quiet, friendly personality and for the patient tenacity with which he applied himself to his chosen problems of study.

<div align="right">T.D.C.</div>

# LIST OF LECTURES GIVEN AT MEETINGS DURING THE YEAR 1958-59

**Summary**

# LIST OF LECTURES GIVEN AT MEETINGS DURING THE YEAR 1958-59

Oct., 1958. MR. K. H. NORTHCOTE: "The Problems of Classification, with Special Reference to Soils".

Nov., 1958. MR. L. W. PARKIN; "Geological Progress in South Australia in the Post-war Period" (Presidential Address).

Apr., 1959. DR. K. THOMSON: "Rugiri, a newly discovered ceremonial site in the Western Desert, Northern Territory".

May, 1959. DR. J. N. BLACK: "Light, Climate, Leaf Area and the Growth of Plant Communities".

June, 1959. SIR RONALD FISHER: "Tobacco and Lung Cancer".

July, 1959. DR. A. F. BIRD: "The Physiology of Root Attraction in Plant Parasitic Nematodes".

Aug., 1959. MR. D. E. SYMON: "The History and Domestication of Subterranean Clover".

Sept., 1959. DR. D. J. SUTTON: "Palaeomagnetism".

# BALANCE SHEET

**Summary**

## ROYAL SOCIETY OF SOUTH AUSTRALIA (INCORPORATED)
### Receipts and Payments for Year ended 30th September, 1959.

| | £ | s. | d. | | £ | s. | d. |
|---|---|---|---|---|---|---|---|
| To Balance, 1/10/5o | 898 | 18 | 5 | By Printing and Publishing Volume 82, | | | |
| ,, Subscriptions | 359 | 17 | 5 | Reprints, etc. | 2,678 | 13 | 1 |
| ,, Government Grant | 1,750 | 0 | 0 | ,, Library Assistants | 196 | 12 | 1 |
| ,, Sale of Publications, etc. | 431 | 12 | 1 | ,, Printing and Stationery | 55 | 17 | 10 |
| ,, Rent of Rooms | 5 | 2 | 0 | ,, Postage and Duty Stamps, etc. | 95 | 0 | 0 |
| ,, Interest— | | | | ,, Cleaning | 67 | 12 | 0 |
| Endowment Fund £239 11 7 | | | | ,, Insurance | 61 | 12 | 5 |
| Savings Bank of | | | | ,, Lighting | 6 | 15 | 5 |
| S.A. 44 14 8 | | | | ,, Sundries | 13 | 0 | 3 |
| | 284 | 6 | 3 | ,, Balance— | | | |
| | | | | Savings Bank of | | | |
| | | | | S.A., Rundle St. £598 8 3 | | | |
| | | | | Less Outstanding | | | |
| | | | | Cheques 43 15 2 | | | |
| | | | | | 554 | 13 | 1 |
| | £3,729 | 16 | 2 | | £3,729 | 16 | 2 |

Audited and found correct.

Adelaide, 5th October, 1959.

F. M. ANGEL　　　　　　　　　　} Hon.
N. S. ANGEL, A.U.A. Com.　　} Auditors.


## ENDOWMENT FUND
### Receipts and Payments for Year ended 30th September, 1959.

| | £ | s. | d. | | £ | s. | d. |
|---|---|---|---|---|---|---|---|
| To Balance, 1/10/58 | 6,110 | 0 | 0 | By Revenue A/c | 239 | 11 | 7 |
| ,, Interest— | | | | ,, Balance— | | | |
| Inscribed Stock £234 1 7 | | | | C'wealth Inscribed | | | |
| Gas Co. 5 10 0 | | | | Stock £6,010 0 0 | | | |
| | 239 | 11 | 7 | S.A. Gas Co. Bonds 100 0 0 | | | |
| | | | | | 6,110 | 0 | 0 |
| | £6,349 | 11 | 7 | | £6,349 | 11 | 7 |

Audited and found correct. The Stock has been verified by certificate and the Gas Co. Bond has been inspected in the hands of the Treasurer.

F. M. ANGEL　　　　　　　　　　} Hon.
N. S. ANGEL, A.U.A. Com.　　} Auditors.

H. WOMERSLEY, Hon. Treasurer.

Adelaide, 5th October, 1959.

# AWARDS OF THE SIR JOSEPH VERCO MEDAL

**Summary**

# AWARDS OF THE SIR JOSEPH VERCO MEDAL

1929 Prof. Walter Howchin, F.G.S.
1930 John McC. Black, A.L.S.
1931 Prof. Sir Douglas Mawson, O.B.E., D.Sc., B.E., F.R.S.
1933 Prof. J. Burton Cleland, M.D.
1935 Prof. T. Harvey Johnston, M.A., D.Sc.
1938 Prof. J. A. Prescott, D.Sc., F.A.C.I.
1943 Herbert Womersley, A.L.S., F.R.E.S.
1944 Prof. J. G. Wood, D.Sc., Ph.D.
1945 Cecil T. Madigan, M.A., B.E., D.Sc., F.G.S.
1946 Herbert M. Hale, O.B.E.
1955 L. Keith Ward, I.S.O., B.A., B.E., D.Sc.
1956 N. B. Tindale, B.Sc.
1957 C. S. Piper, D.Sc.
1959 C. G. Stephens, D.Sc.

# LIST OF FELLOWS
## AS AT 30th SEPTEMBER, 1959.

Those marked with an asterisk (°) have contributed papers published in the Society's Transactions. Those marked with a dagger (†) are Life Members.

Any change in address or any other changes should be notified to the Secretary.

*Note.*—The publications of the Society are not sent to those members whose subscriptions are in arrears.

| Date of Election | Date of Honorary Election | HONORARY FELLOWS |
|---|---|---|
| 1895 | 1949 | °CLELAND, Prof. J. B., M.D., Dashwood Road, Beaumont, S.A.—*Verco Medal, 1933; Council, 1921-26, 1932-37; President, 1927-28, 1940-41; Vice-President, 1926-27, 1941-42.* |
| 1913 | 1955 | °OSBORN, Prof. T. G. B., D.Sc., St. Mark's College, Pennington Terrace, North Adelaide—*Council, 1915-20; 1922-24; Vice-President, 1924-25, 1926-27; President, 1925-26.* |
| 1912 | 1955 | °WARD, L. K., I.S.O., B.A., B.E., D.Sc., 22 Northumberland Street, Heathpool, Marryatville, S.A.—*Council, 1924-27, 1933-35; Vice-President, 1927-28; President, 1928-30.* |

| Date of Election | FELLOWS |
|---|---|
| 1946. | °ABBIE, Prof. A. A., M.D., D.Sc., Ph.D., University of Adelaide. |
| 1958. | °ABELE, K., Dr. Phil. (Marburg), Dr.Phil.Nat. (Tartu-Dorpat), M.Sc. (Riga), 42 Kildonan Road, Warradale Park, S.A. |
| 1959. | AITKEN, P., B.Sc., South Australian Museum, North Terrace., Adelaide, S.A. |
| 1927. | °ALDERMAN, Prof. A. R., Ph.D., D.Sc., F.G.S., Department of Geology, University of Adelaide—*Council, 1937-42, 1954-57.* |
| 1951. | ANDERSON, Mrs. S. H., B.Sc., 31 Lakeman Street, North Adelaide. |
| 1935. | °ANDREWARTHA, H. G., M.Ag.Sc., D.Sc., Zoology Dept., University of Adelaide—*Council, 1949-50; Vice-President, 1950-51, 1952-53; President, 1951-52.* |
| 1935. | °ANDREWARTHA, Mrs. H. V., B.Agr.Sc., M.Sc. (nee H. V. Steele), 29 Claremont Avenue, Netherby, S.A. |
| 1929. | °ANGEL, F. M., 34 Fullarton Road, Parkside, S.A. |
| 1939. | °ANGEL, Miss L. M., M.Sc., 2 Moore Street, Toorak, Adelaide, S.A. |
| 1945. | °BARTLETT, H. K., L.Th., 2 Abbotshall Road, Lower Mitcham, S.A. |
| 1958. | BAUER, F. H., Australian National University, Canberra, A.C.T. |
| 1950. | BECK, R. G., B.Ag.Sc., R.D.A., Lynewood Park, Mil-Lel, via Mount Gambier, S.A. |
| 1932. | BEGG, P. R., D.D.Sc., L.D.S., Shell House, 170 North Terrace, Adelaide. |
| 1928. | BEST, R. J., D.Sc., F.A.C.I., Waite Institute (Private Mail Bag, No. 1), Adelaide. |
| 1956. | BLACK, A. B., A.S.A.S.M., M.I.M.M., 38 Woodcroft Avenue, St. Georges, S.A. |
| 1934. | BLACK, E. C., M.B., B.S., Magill Road, Tranmere, Adelaide. |
| 1950. | BONNIN, N. J., M.B., B.S., F.R.C.S. (Eng.), F.R.A.C.S., 40 Barnard Street, North Adelaide, S.A. |
| 1945. †° | BONYTHON, C. W., B.Sc., A.A.C.I., Romalo House, Romalo Avenue, Magill, S.A. |
| 1940. | BONYTHON, Sir J. Lavington, 263 East Terrace, Adelaide. |
| 1945. | °BOOMSMA, C. D., M.Sc., B.Sc.For., 6 Celtic Avenue, South Road Park, S.A. |

Date of
Election

1957. °Brookes, Miss H. M., Dept. of Entomology, Waite Institute (Private Mail Bag, No. 1), Adelaide.
1957. Buick, W. G., B.A., c/o Country Lending Service, Public Library, South Australia.
1944. °Burbidge, Miss N. T., M.Sc., C.S.I.R.O., Div. Plant Industry, P.O. Box 109, Canberra, A.C.T.
1925. Burdon, R. S., D.Sc., Physics Dept., University of Adelaide—*Council*, 1946-49.
1958. Buring, I., 51 Richmond Road, Westbourne Park, S.A.
1922. °Campbell, Prof. T. D., D.D.Sc., D.Sc., 24 Lymington Street, Tusmore, S.A.—*Council*, 1928-32, 1935, 1942-45; *Vice-President*, 1932-34; *President*, 1934-35.
1939. Carrodus, B. B., R.D.Oen., St. Mark's College, North Adelaide, S.A.
1953. Carter, A. N., B.Sc., 70 Madeline Street, Burwood, E.13, Victoria.
1957. °Chippendale, G. M., B.Sc., Lindsay Avenue, Alice Springs, N.T.
1929. Christie, W., M.B., B.S., 7 Walter Street, Hyde Park, Adelaide, S.A.—*Treasurer*, 1933-38.
1955. Clothier, E. A., Hydroelectric Commission, Hobart, Tas.
1949. Colliver, F. S., Geology Department, University of Queensland.
1929. °Cotton, B. C., F.R.Z.S., J.P., S.A. Museum, North Terrace, Adelaide—*Council*, 1943-46, 1948-49; *Vice-President*, 1949-50, 1951; *President*, 1950-51; *Programme Secretary*, 1959-.
1956. Crawford, A. R., B.Sc., Dept. of Mines, Adelaide.
1956. Daily, B., Ph.D., S.A. Museum—*Programme Secretary*, 1957-59.
1951. Davidson, A. L. C., Ph.D., B.Sc., c/o Messrs. Simpson & Brookman, 28 Pirie Street, Adelaide, S.A.
1950. Deland, C. M., M.B., B.S., D.P.H., D.T.M., 29 Gilbert Street, Goodwood, S.A.—*Council*, 1949-51, 1954-59; *Vice-President*, 1951-52, 1953-54; *President*, 1952-53.
1930. Dix, E. V., Box 12, Aldgate, S.A.
1957. Doull, K. M., M.Ag.Sc., Waite Institute (Private Mail Bag, No. 1), Adelaide.
1959. Dunlop, P. R. G., B.Sc., 13 Walton Ave., Clearview, S.A.
1944. Dunstone, S. M. L., M.B., B.S., 170 Payneham Road, St. Peters, Adelaide.
1931. Dwyer, J. M., M.B., B.S., 105 Port Road, Hindmarsh, S.A.
1933. *Eardley, Miss C. M., M.Sc., F.L.S., University of Adelaide—*Council*, 1943-46.
1945. °Edmonds, S. J., B.A., M.Sc., Ph.D., Zoology Department, University of Adelaide—*Council*, 1954-55; *Programme Secretary*, 1955-56; *Secretary*, 1956-57.
1902. *Enquist, A. G., 19 Farrell Street, Glenelg, S.A.—*Council*, 1949-53.
1956. °Eichler, H., Dr.rer.nat., State Herbarium, Botanic Garden, Adelaide.
1959. Fielder, D. R., B.Sc., Dept. of Zoology, University, North Terrace, Adelaide, S.A.
1927. °Finlayson, H. H., 305 Ward Street, North Adelaide—*Council*, 1937-40.
1951. Fisher, R. H., 21 Seaview Road, Lynton, South Australia.
1958. °Forbes, B. G., Ph.D., F.G.S., 9 Flinders Road, Hillcrest, S.A.
1958. Ford, A. W., F.I.C.S., A.C.C.S., 380 South Terrace, Bankstown, N.S.W.
1959. Forde, N., Dip.For., C.S.I.R.O., Canberra, A.C.T.
1954. Gibson, A. A., A.W.A.S.M., Mines Department, Adelaide.
1953. °Glaessner, M. F., D.Sc., c/o Geology Department, University of Adelaide—*Council*, 1953-54; *Vice-President*, 1958-59.
1927. Godfrey, F. K., 5 Robert Street, Paynehani, South Australia.
1935. |Goldsack, H., Coromandel Valley, S.A.
1959. Green, Miss L. M. A., B.A., M.Sc., Dept. of Anatomy and Histology, University, Adelaide, S.A.
1948. Gross, G. F., M.Sc., South Australian Museum, Adelaide—*Secretary*, 1950-53.
1944. Guppy, D. J., B.Sc., c/o W.A. Petroleum Co., 251 Adelaide Terrace, Perth, W.A.
1922. °Hale, H. M., O.B.E., c/o S.A. Museum, North Terrace, Adelaide—*Verco Medal*, 1946; *Council*, 1931-34, 1950-53, 1956; *Vice-President*, 1934-36, 1937-38; *President*, 1936-37; *Treasurer*, 1938-50, 1953-56.
1949. Hall, D. R., Tea Tree Gully, S.A.
1930. |Hancock, N. L., 3 Bewdley, 66 Beresford Road, Rose Bay, N.S.W.
1953. °Hansen, I. V., B.A., Queen Elizabeth School, Crediton, Devon, England.
1946. °Hardy, Mrs. J. E. (nee A. C. Beckwith), M.Sc., Box 62, Smithton, Tas.
1944. Harris, J. R., B.Sc., c/o Waite Institute (Private Mail Bag, No. 1), Adelaide.
1958. Hayball, J. F., B.Sc., 68 Pleasant Avenue, Clandore, S.A.
1944. Herriot, R. I., B.Agr.Sc., 49 Halsbury Avenue, Kingswood, S.A.
1951. Hocking, L. J., 46 Kauri Parade, Seacliff, S.A.
1959. Horwitz, R. G. H., D.Sc., 6 Vardon Street, Seacombe Gardens, S.A.
1924. °Hossfeld, P. S., Ph.D., 132 Fisher Street, Fullarton, S.A.
1944. Humble, D. S. W., M.P.S., J.P., 238 Payneham Road, Payneham, S.A.
1947. °Hutton, J. T., B.Sc., A.S.A.S.M., 10 Bellevue Place, Unley Park—*Council*, 1957-59.

1928. Iredale, P., 14 Wyatt Road, Burnside, S.A.

1945. °Jessup, R. W., M.Sc., Division of Plant Industry, C.S.I.R.O., P.O. Box 109, City, Canberra, A.C.T.

1950. °Johns, R. K., B.Sc., Department of Mines, Adelaide, S.A.

1957. Johnson, B., B.Sc.Agr., Ph.D., Waite Institute (Private Mail Bag, No. 1), Adelaide.

1958. °Johnson, W., B.Sc. (Hons.), 33 Ryan Avenue, Woodville West, S.A.

1954. Keats, A. L., B.E., 44 LeFevre Terrace, North Adelaide.

1939. †Khakhar, H. M., Ph.D., M.B., F.R.G.S., Khakhar Buildings, C.P. Tank Road, Bombay, India.

1919. °King, D., M.Sc., c/o Commercial Bank of Australia, King William St., Adelaide, S.A.

1933. °Kleeman, A. W., Ph.D., Dept. of Geology, University of Adelaide—Secretary, 1945-48; Vice-President, 1948-49, 1950-51; President, 1949-50.

1922. Lendon, G. A., M.D., B.S., F.R.C.P., c/o Elder's Trustee and Executor Co. Ltd., 37 Currie Street, Adelaide, S.A.

1958. Lindsay, H. A., 110 Cross Road, Highgate, S.A.

1948. Lothian, T. R. N., N.D.H. (N.Z.), Director, Botanic Garden, Adelaide—Treasurer, 1952-53; Council, 1953-57; Vice-President, 1957-58; President, 1958, 1959.

1931. ^Ludbrook, Mrs. N. H., M.A., Ph.D., D.I.C., F.G.S., Department of Mines, Adelaide —Council, 1958-59.

1953. Maelzer, D. A., B.Sc. (Hons.), Waite Institute (Private Mail Bag, No. 1), Adelaide.

1939. Marshall, T. J., M.Agr.Sc., Ph.D., C.S.I.R.O., Division of Soils (Private Mail Bag, No. 1), Adelaide—Council, 1948-52.

1959. Martin, Miss H. A., 43 Dunrobin Road, Brighton, S.A.

1920. Mayo, Sir Herbert, LL.B., Q.C., 19 Marlborough Street, College Park, S.A.

1950. Mayo, G. M. E., B.Ag.Sc., Ph.D., 146 Melbourne Street, North Adelaide.

1943. McCarthy, Miss D. F., B.A., B.Sc., 17 Brookside Ave., Tranmere.

1948. McCulloch, R. N., M.B.E., B.Sc., B.Agr.Sc., Roseworthy Agricultural College, Roseworthy, S.A.

1945. †*Miles, K. R., D.Sc., F.G.S., 11 Church Road, Mitcham, S.A.

1951. Miles, J. A. R., M.A., M.D., B.Chir. (Cant.), University of Otago, N.Z.

1952. Milne, K. L., F.C.A., 14 Burlington Street, Walkerville, S.A.

1939. Mincham, V. H., 30 Wainhouse Street, Torrensville, S.A.

1958. Mirams, R. G., B.Sc., 5 Myrtle Rd., Seacliff, S.A.

1951. *Mitchell, F. J., South Australian Museum, North Terrace, Adelaide, S.A.—Treasurer, 1959-.

1933. Mitchell, Prof. Sir M. L., M.Sc., c/o Elder's Trustee and Executor Co. Ltd., 37 Currie Street, Adelaide.

1925. †Mitchell, Prof. Sir W., K.C.M.G., M.A., D.Sc., Fitzroy Terrace, Prospect, S.A.

1938. Moorhouse, F. W., M.Sc., Chief Inspector of Fisheries, Simpson Buildings, Gawler Place, Adelaide.

1936. °Mountford, C. P., 25 First Avenue, St. Peters, Adelaide.

1957. ^Mumme, Ivan A., B.Sc. (Hons.), Dept. of Mines, Adelaide.

1944. Murrell, J. W., Engineering and Water Supply Dept., Victoria Square, Adelaide.

1944. Ninnes, A. R., B.A., R.D.A., 62 Sheffield Street, Malvern, S.A.

1945. °Northcote, K. H., B.Agr.Sc., A.I.A.S., C.S.I.R.O., Division of Soils, Private Mail Bag, No. 1, Adelaide.

1930. Ockenden, G. P., B.A., 108 Hockey Street, Whyalla South, S.A.

1958. O'Driscoll, E. S., B.Sc., 9 Vinall Street, Dover Gardens, S.A.

1937. °Parkin, L. W., M.Sc., A.S.T.C., Mines Dept., Adelaide — Secretary, 1953-56; Vice-President, 1956-57, 1958-59; President, 1957-58.

1949. Parkinson, K. J., B.Sc., Birdwood, S.A.

1929. Paull, A. G., M.A., B.Sc., 10 Milton Avenue, Fullarton Estate, S.A.

1926. °Piper, C. S., D.Sc., C.S.I.R.O., Division of Soils, Private Mail Bag, No. 1, Adelaide— Verco Medal, 1957; Council, 1941-43; Vice-President, 1943-45, 1946-47; President, 1945-1946.

1948. Powrie, J. K., B.Sc., Waite Institute (Private Mail Bag, No. 1), Adelaide, S.A.

1925. °Prescott, Prof. J. A., C.B.E., D.Sc., F.R.A.C.I., F.R.S., 82 Cross Road, Myrtle Bank, S.A.—Verco Medal, 1938; Council, 1927-30, 1935-39; Vice-President, 1930-32; President, 1932-33; Editor, 1955-.

1957. °Pringle, Miss L. A. B., Box 876e, G.P.O., Adelaide.

1945. °Pryor, L. D., M.Sc., Dip.For., 32 La Perouse Street, Griffith, Canberra, A.C.T.

1950. °Rattigan, J. H., M.Sc., Box 229e, G.P.O., Melbourne, Victoria.

1944. Riceman, D. S., M.Sc., B.Agr.Sc., C.S.I.R.O., Division of Biochemistry, Adelaide.

1947. Riedel, W. R., B.Sc., c/o Scripps Institution of Oceanography, Dept. of Palaeontology, University of California, La Jolla, California, U.S.A.

1947. Rix, C. E., 42 Waymouth Avenue, Glandore, S.A.

1953. Rogers, Prof. W. P., Ph.D., F.A.A., Zoology Department, University of Adelaide.

1951. Rowe, S. A., 22 Shelley Street, Firle, S.A.

1950. Rudd, Prof. E. A., B.Sc., A.M., University of Adelaide, S.A.

1951. Russell, L. D., c/o Adelaide Boys' High School, West Terrace, Adelaide, S.A.

1945. Rymill, J. R., Old Penola Estate, Penola, S.A.

1933. Schneider, M., M.B., B.S., 175 North Terrace, Adelaide,

1959. Schodde, R., 23 French Street, Netherby, S.A.

1951. °Scott, T. D., M.Sc., S.A. Museum, North Terrace, Adelaide, S.A.— *Programme Secretary*, 1953-54, 1956-57; *Secretary*, 1957-59.

1957. Sharman, G. B., B.Sc., Department of Zoology, University, North Terrace, Adelaide, S.A.

1925. °Sheard, H., Port Elliot, S.A.

1936. °Sheard, K., D.Sc., Fisheries Research Div., C.S.I.R.O., Division of Fisheries and Oceanography, University of W.A., Nedlands, W.A.

1954. Sheppield, R. C., B.Sc., c/o Department of Mines, Adelaide.

1934. Shinkfield, R. C., 57 Canterbury Avenue, Trinity Gardens, S.A.

1925. †Smith, Sir Tom Bakr, Kt., B.A., 25 Currie Street, Adelaide.

1941. °Smith, T. L., B.Sc., Dept. of Geography, University of Sydney, N.S.W.

1941. °Southcott, R. V., M.D., B.S., D.T.M. & H., 13 Jasper Street, Hyde Park, S.A.— *Council*, 1949-51, 1952-53, 1957-; *Treasurer*, 1951-52; *Vice-President*, 1953-54, 1955-56; *President*, 1954-55.

1936. Southwood, A. R., M.D., M.S. (Adel.), M.R.C.P., 170 North Terrace, Adelaide.

1947. °Specht, R. L., Ph.D., Botany Department, University of Adelaide— *Council*, 1951-52, 1958-59; *Programme Secretary*, 1952-55.

1936. †°Sprigg, R. C., M.Sc., 5 Baker Street, Somerton Park.

1951. Steadman, Rev. W. R., 8 Blairgowrie Road, St. Georges, S.A.

1947. Spurling, M. B., B.Ag.Sc., Horticultural Branch, Department of Agriculture, Box 901 E, G.P.O., Adelaide.

1949. °Spry, A. H., M.Sc., Geology Department, University of Tasmania.

1938. °Stephens, C. G., D.Sc., C.S.I.R.O., Division of Soils, Private Mail Bag, No. 1, Adelaide—*Verco Medal*, 1959; *Council*, 1952-54; *Vice-President*, 1954-55, 1956-57; *President*, 1955-56.

1955. Swaine, C. D., M.B., B.S., 220 Esplanade, Largs North, S.A.

1932. Swan, D. C., M.Sc., Waite Institute (Private Mail Bag. No. 1), Adelaide—*Secretary*, 1940-42; *Vice-President*, 1946-47, 1948-49; *President*, 1947-48; *Council*, 1953-58.

1951. Swirski, P., M.Ag.Sc., 11 Wall Street, Norwood, S.A.

1934. Symons, I. G., 35 Murray Street, Lower Mitcham, S.A.—*Editor*, 1947-55; *Council*, 1955-58.

1956. Taylor, D. J., Dept. of Entomology, Waite Institute (Private Mail Bag, No. 1), Adelaide, S.A.

1929. °Taylor, J. K., B.A., M.Sc., C.S.I.R.O., Division of Soils, Private Mail Bag, No. 1, Adelaide—*Council*, 1940-43, 1947-50; *Librarian*, 1951-52; *Vice-President*, 1952-53, 1954-55; *President*, 1953-54; *Council*, 1955.

1955. Thatcher, D., B.Sc., Department of Mines, Adelaide.

1948. °Thomas, I. M., M.Sc. (Wales), Department of Zoology, University of Adelaide— *Secretary*, 1948-50; *Council*, 1950-53; *Vice-President*, 1955-56, 1957-58; *President*, 1956-57; *Assistant Editor*, 1958-.

1938. ᵇThomas, Mrs. I. M. (nee P. M. Mawson), M.Sc., 18 Dunluce Ave., Brighton, S.A.

1957. Thomas, J., B.Sc., Woodleigh Road, Blackwood, S.A.

1940. ᵃThompson, Capt. J. M., 135 Military Road, Semaphore South, S.A.

1959. Thomson, B. P., M.Sc., 33 Oaklands Road, Parkholme, S.A.

1923. ⁺Tindale, N. B., B.Sc., South Australian Museum, Adelaide—*Verco Medal*, 1956; *Secretary*, 1935-36; *Council*, 1946-47; *Vice-President*, 1947-48, 1949-50; *President*, 1948-49; *Librarian*, 1952-.

1955. °Tucker, B. M., B.Sc., C.S.I.R.O., Division of Soils, Private Mail Bag, No. 1, Adelaide.

1959. Twidale, C. R., Ph.D., M.Sc., Dept. of Geography, University, North Terrace, Adelaide, S.A.

1959. ᵇTyler, M. J., Dept. of Physiology, University, Adelaide, S.A.

1950. Veitch, J. T., Box 92, Port Lincoln, S.A.

1953. Waterman, H. A., B.A., M.A., Ph.D., Wayne State University, Detroit, Michigan, U.S.A.

1954. Webb, B. P., M.Sc., Mines Dept., Rundle Street, Adelaide.

1954. Wells, C. B., B.Ag.Sc., Broadlees, Waverley Ridge, Crafers, S.A.

1948. °Whittle, A. W. G., M.Sc., Mines Department, Adelaide.

1950.    WILLIAMS, L. E., "Dumosa," Meningie, S.A.
1946.    *WILSON, A. F., D.Sc., Dept. of Geology, University of W.A., Nedlands, W.A.
1938.    *WILSON, J. O., 42 Wilson Terrace, DaCosta Park, Glenelg, S.A.
1933.    *WOMERSLEY, H., F.R.E.S., A.L.S. (Hon. causa), S.A. Museum, Adelaide — *Verco*
           *Medal*, 1943; *Secretary*, 1936-37; *Editor*, 1937-43, 1945-47; *President*, 1943-44;
           *Vice-President*, 1944-45; *Rep. Fauna and Flora Protection Committee*, 1945;
           *Treasurer*, 1950-51, 1956-59.
1954.    *WOMERSLEY, H. B. S., Ph.D., Botany Department, University of Adelaide.
1944.    WOMERSLEY, J. S., B.Sc., Dept. of Forests, Lae, New Guinea.
1923.    *WOOD, PROF. J. G., D.Sc., Ph.D., F.A.A., Botany Dept., University of Adelaide—*Verco*
           *Medal*, 1944; *Council*, 1938-40; *Vice-President*, 1940-41, 1942-43; *Rep. Fauna and*
           *Flora Board*, 1940-; *President*, 1941-42; *Council*, 1944-48.
1957.    WOODS, R. V., B.Sc., Mt. Crawford, S.A.
1949.    YEATES, J. N., A.M.I.E., A.M.I.M.E., Highways and Local Government Dept.,
           Adelaide.
1944.    ZIMMER, W. J., Dip.For., F.L.S. (Lon.), 7 Rupert Street, Footscray West, W.12, Vict.

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*Names printed in italics as separate entries indicate that the forms are new to science.*

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